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AGE DIFFERENCES IN THE WORK CAPACITY OF ALBERTA SECONDARY SCHOOL STUDENTS AS MEASURED BY THE ASTRAND PREDICTED MAXIMAL OXYGEN INTAKE TEST

by

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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled, "Age Differences in the Work Capacity of Alberta Secondary School Students as Measured by the Astrand Predicted Maximal Oxygen Intake Test," submitted by Robert William Ker Norman in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The purpose of the project was to establish norms and to determine age differences in work capacity as estimated by the Astrand-Ryhming nomogram for the prediction of maximal oxygen intake.

The major portion of the investigation involved the field study of 417 secondary school females and 499 secondary school males ages 14 to 21 years. The subjects at each school were selected through the use of a table of random numbers. Three per cent of every secondary school population in each of 44 towns and cities in the province of Alberta were tested. These towns and cities were chosen by the Edmonton Branch of the Dominion Bureau of Statistics and were considered, by that organization, to be representative of the Alberta population on a socio-economic, geographic, industrial and population density basis.

Each subject was required to ride a bicycle ergometer for six minutes set at a work load estimated by the investigators to cause the heart rate to plateau between 120 and 170 beats per minute. This plateau was accepted as representing the steady state heart rate when the difference between heart frequencies at the end of the fifth and the sixth minute of exercise did not exceed five beats per minute. The maximal oxygen intake of the subject was predicted from the steady state heart rate and the work load by means of the nomogram devised by Astrand and Ryhming (6). The values were expressed in liters per minute (l/min) and in milliliters per kilogram of body weight per minute (ml/kg/min). Heart rates were determined by carotid artery palpation.

Norms of predicted maximal oxygen intake were established for

males and for females ages 15 to 19 years.

No significant differences were found among any of the age groups in predicted maximal oxygen intake whether expressed per kilogram of body weight or in liters per minute for males or for females.

Sixteen per cent of the variance in predicted maximal oxygen intake for males and 14 per cent for females was accounted for by variance in body weight. Dividing predicted maximal oxygen intake values by body weight to equate subjects therefore, over-compensated for the influence that body weight had on this parameter. The correlation of height with predicted maximal oxygen intake was of approximately the same magnitude as that between weight and predicted maximal oxygen intake. However, the first order partial correlations showed that this relationship was spurious and attributable to the correlation of weight with height.

The correlation of pre-exercise pulse rate with predicted maximal oxygen intake was negative in all age groups and accounted for 12 to 28 per cent of the variance for males and 14 to 29 per cent for females over the age range studied. It was concluded that an elevated pre-exercise pulse rate raised the level at which the pulse rate plateaued during submaximal work and consequently tended to lower the predicted maximal oxygen intake.

A laboratory experiment of a test-retest design was conducted in which the reliability coefficient for steady state heart rates was established. The purpose was to determine whether the Astrand Predicted Maximal Oxygen Intake Test provided estimates of maximal oxygen intake which were sufficiently reproducible to allow the detection of differences

among individuals of secondary school age.

Twenty-three males and twenty-three females ages 14 to 18 years were evaluated on two different days using the Astrand Predicted Maximal Oxygen Intake Test. The test was administered as described above. Heart rates were estimated simultaneously by means of an electrocardiograph and by carotid artery palpation.

The reliability coefficient for steady state heart rate for males was 0.80 and for females, 0.72. For predicted maximal oxygen intake in liters per minute, calculated by using the Astrand-Ryhming nomogram, the values were 0.84 and 0.71 respectively. The coefficients were adequate to permit the detection of individual differences in these parameters.

When predicted maximal oxygen intake was expressed per kg. of body weight the reliability coefficient remained at 0.84 for males but was 0.53 for females. The measured physiological parameter (steady state heart rate) was shown to be reproducible for both sexes but for females, the calculated maximal oxygen intake in milliliters per kilogram per minute was not. It appeared therefore, that no correlation advantage was gained by converting the heart rates to maximal oxygen intake and for females it was disadvantageous to express their scores per kilogram of body weight.

The correlations between the electrocardiograph heart rate recordings and the carotid palpation estimations (0.984, 0.970, 0.994 for the three experimentors) indicated that the palpation technique was adequate for field testing if the experimentor established a correction factor for his own palpation readings.

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CHAPTER I

STATEMENT OF THE PROBLEM

People in the field of Physical Education, Medicine, Physical Rehabilitation and similar professions are concerned about the implications of regular physical exercise on the human organism. The term "physical fitness" represents a body of partially understood phenomena and a complex of unsatisfactorily answered questions.

Firstbrook (42:17,18), formerly of the Department of Physiological Hygiene at the University of Toronto, touched upon several of these issues when he asked, "What is the effect of regular physical exercise or physical training on health and longevity?" and, "Does regular exercise of such and such a type prevent or slow the development of coronary atherosclerosis? "Is the blood cholesterol level lowered? Is the blood less coagulable? If so, how are these effects brought about?"

As Firstbrook recognized, when "health" is broadly defined to include enjoyment of life, and a general feeling of physical well-being, reported effects of regular exercise such as being "more alert," and "being better able to withstand physical and mental stresses" are not quantifiable scientifically but are, nonetheless, very important. However, when "health" is defined as simply the absence of disease one can reasonably demand answers based on scientific investigation.

Although Montoye (74) has cited some evidence to indicate that discrete amounts of exercise help to prevent the condition under which

coronary heart disease occurs, the facts are not yet conclusive (34,74). As a result, before an individual is willing to subject himself to a type of work which, in many instances, has previously become physical drudgery, he asks two questions. "Is it really important that I become 'fit'?" and "How long and how intensely do I have to train to attain a desirable level of 'fitness'?"

The answers are not readily available partly because there has been considerable debate amongst physiologists, physical educators and medical doctors as to what "physical fitness" is.

Clarke defines physical fitness generally as (26:16):

> The development and maintenance of a sound physique and of soundly functioning organs, to the end that the individual realizes his capacity for physical activity, unhampered by physical drains or by a body lacking in physical strength and vitality.

Gallagher and Brouha classify physical fitness as having three main components (cited in 29:488):

1. Static Fitness--which involves a well developed, well nourished and organically sound body.

2. Functional Fitness--which embraces the ability to do strenuous work.

3. Specialized Fitness--which embraces the ability of the subject to perform specific skilled tasks.

Each main division has subdivisions. Thus "functional fitness" includes the ability to perform moderate work (where a steady-state in respiratory and cardiovascular response is attained), the ability to perform under conditions of severe muscular effort (involving the acquisition of a rapidly increasing oxygen debt), the ability to move with speed, muscular strength and possibly the ability to perform, for

prolonged periods, moderate exercise to fatigue.

On a slightly different approach Darling states (34:141):

> Fitness apparently, consists in the ability of the organism to maintain the various internal equilibria as closely as possible to the resting state during strenuous exertion and to restore promptly after exercise any equilibriums which have been disturbed.

This seems to exclude the concept of a state of readiness or capability of the muscles to initiate an activity as being an integral part of fitness but obviously implies a large responsibility on the circulatory and respiratory systems in the readjustment process.

Clarke (26) suggests that physical fitness is composed of cardio-respiratory endurance, muscular strength and muscular endurance and that measures of each should be included in any fitness battery. Other investigators (5,79) feel that maximal oxygen intake is the best measure of physical fitness available at the present since, according to Astrand (14), the measurement of maximal oxygen intake (aerobic work capacity) of a subject when performing muscular exercise gives the maximum rate of energy output by combustion within the body.

Some divergence of opinion therefore exists among well known investigators in the area of "physical work capacity," a term not precisely synonymous with but more definitive than "physical fitness," as to what components go together to produce this entity and how best to measure the components.

Astrand attributes this divergence to a lack of differentiation between the terms "work capacity" and "physical condition" (5:140):

> Work capacity is a synthesis of aerobic and anaerobic capacity, mechanical efficiency and physical condition whereas physical

> condition states how the circulation, respiration, muscles, etc., are fit for hard work of long duration. The heaviness of the work must be related to the individual's work capacity. Thus, working capacity is quantitative and physical condition is more qualitative.

However, Wahlund (91:71) defines "work capacity" for practical use as, ". . .the maximum working intensity consistent with a steady state," a somewhat more limited definition than that offered by Rodahl, which is (79:500), ". . .the individual's total ability to perform prolonged physical work. For all practical purposes, this means the ability of the cardiopulmonary system to take up, transport and give off oxygen to the muscle tissues for performance of physical work."

Fitness, then, seems to be somewhat distinguishable from work capacity which is closely related to maximal oxygen intake because the former can be associated with the rate of adaptation to stress (qualitative) whereas work capacity gives an indication of the degree of adaptation possible (quantitative). Since aerobic capacity probably influences the rate of adaptation it is impossible to divorce the two terms completely.

It is therefore readily apparent that the question of physical fitness is not as clear-cut as many people would lead us to believe, either in definition, in components synthesizing the definition, or in the measurement of the components.

If physical fitness is to remain one of the primary objectives of physical education then an attempt should be made to answer or at least to clarify the nebulous concepts which pervade the area. Certainly this will not be accomplished in one study, nor will it be accomplished if

fundamental studies are not undertaken. Fortunately, steps are being taken in this direction. The Canadian Association for Health, Physical Education and Recreation is currently establishing nation-wide norms for children between the ages of 7 and 17 years on a motor performance and fitness battery and has received a federal grant to include a work capacity evaluation of a comparable sample. Since it is impossible to state what an absolute desirable level of fitness is at the present time an arbitrary criterion must be set. Most often in comprehensive studies this criterion is a person's standing in relation to the rest of the population. The weakness with this type of standard, of course, is the fact that the population mean may be low. Nevertheless, this information offers a starting point for further necessary studies in the area of physical fitness which, it is hoped, will eventually satisfy the now unanswerable queries. Before any criticism or praise as to the level of physical fitness of Canadians can be justified it is essential to know what that level is, not for isolated groups of people, but for the population as a whole.

Purpose of the Study

The present study was designed to establish norms of the "working capacity" of a sample of Alberta youth from grades X to XII as measured by the Astrand Predicted Maximal Oxygen Intake Test and to determine age differences for males and females of the sample in predicted maximal oxygen intake expressed per kilogram of body weight and in liters per minute.

Subproblems. Data was collected which allowed the following analyses to be made.

1. An analysis of the relationship between predicted maximal oxygen intake and body weight and between predicted maximal oxygen intake and height.

2. An analysis of the relationship between predicted maximal oxygen intake and pre-exercise pulse rate.

In addition to the field study, a laboratory experiment was conducted for the purpose of determining the suitability of the Astrand-Ryhming nomogram for predicting the maximal oxygen intake of a sample of teenage subjects.

An analysis was made of the inter-individual variability and the intra-individual variability of the steady state heart rate which in turn influences the predicted maximal oxygen intake. From this information the test-retest reliability coefficient was calculated and the ability of the test to differentiate between individuals was determined.

An analysis of the relationship between heart rates recorded simultaneously by means of an electrocardiograph and by carotid artery palpation, at both low and high pulse frequencies, was conducted to determine the accuracy of the palpation technique.

Justification of the Study

Concern about "fitness" has been expressed at the highest government levels recently in both Canada and in the United States.

> Our schools have been urged to give increased attention to the physical well-being of their students, yet there has been no noticeable improvement.
> . . . . . .

This is a national problem and it requires national action.

The harsh fact of the matter is that there are an increasingly large number of young Americans who are neglecting their bodies--whose physical fitness is not what it should be--who are getting soft, and such softness on the part of the individual citizens can help to strip and destroy the vitality of a nation (61:4).

Her Majesty, by and with the advice and consent of the Senate and House of Commons of Canada, enacts as follows:-

Short Title

1. This Act may be cited as the "Fitness and Amateur Sport Act."

Objects and Powers

3. The objects of this Act are to encourage, promote and develop fitness and amateur sport in Canada, and, without limiting the generality of the foregoing, the Minister may, in furtherance of such objects,

(a) provide assistance for the promotion and development of Canadian participation in national and international amateur sports;
(b) provide for the training of coaches and such other personnel as may be required for the purposes of this Act;
(c) provide bursaries or fellowships to assist in the training of necessary personnel;
(d) undertake or assist in research or surveys in respect of fitness and amateur sport;
(e) arrange for national and regional conferences designed to promote and further the objects of this Act;
(f) provide for the recognition of achievement in respect of fitness and amateur sport by the grant or issue of certificates, citations or awards of merit;
(g) prepare and distribute information relating to fitness and amateur sport;
(h) assist, co-operate with and enlist the aid of any group interested in furthering the objects of this Act;
(i) co-ordinate federal activities related to the encouragement, promotion and development of fitness and amateur sport, in co-operation with any other departments or agencies of the Government of Canada carrying on such activities; and
(j) undertake such other projects or programmes, including the provision of assistance therefor, in respect of fitness and amateur sport as are designed to promote and further the objects of this Act.

. . . . . .

General

10. The Minister of Finance shall, upon the certificate of the Minister, pay out of the Consolidated Revenue Fund such amounts not exceeding in the aggregate five million dollars in any one fiscal year as may be required for the purposes of this Act (43:421,422,424).

The former quotation was composed of excerpts of a speech by the late President John F. Kennedy in 1961 in support of a programme to make health and physical fitness a primary national concern. The latter citations are sections of the "Fitness and Amateur Sport Act" assented to by the Canadian Federal Legislature on September 29, 1961. Both proclaim national concern, by the respective governments, with regard to the fitness level of their people and both imply general public awareness of the existence of a problem. The justification of fitness research is, consequently, self-evident. Inconsistencies in experimental findings and incompleteness in the literature supporting the answers to fundamental questions pertaining to physical fitness emphasizes the acute need for basic research in this area. The obvious starting place is to determine what the level of physical fitness is in Canada, then, if necessary, studies may be conducted to determine how to rectify the situation. This study provides a set of norms based on the results of approximately 1,000 Alberta high school students on the Astrand Predicted Maximal Oxygen Intake Test and allows the comparison of subsequent test results of children of the same population with these provincial means.

A knowledge of age differences in work capacity may facilitate the recognition of abnormal cardio-respiratory development of children and could provide an objective control of the physical educator's and parent's expectations of the child's work output if the energy costs of various forms of activity were known. Pubertal changes may affect a child's work capacity and an investigation of these changes, if any, is

being conducted in this study, as far as the data permits, to complement work already completed by Astrand (5), Bengtsson (19), Cummings (30), and others.

For middle-aged people, knowledge of their work capacity is becoming increasingly important with respect to job placement since this age group is rapidly expanding in numbers. But if valid studies of age differences in working capacity are to be conducted a test which permits all age groups to perform is essential. In Canada at the present time, no test exists, or rather, no test of this type is being used to any extent. For a school or any practical situation, particularly where very young or older persons are involved, the prerequisites of such a test are as follows:

1. It must be submaximal permitting an evaluation to be made without exhausting the subject thus allowing a subject of any age to perform it.
2. It must require a minimum of training of the investigator, be easy to administer and require little time.
3. It must require a minimum of skill on the part of the subject, but at the same time, involve large muscle groups if oxygen intake is being measured.
4. It must be of reasonably low cost.

The Astrand Predicted Maximal Oxygen Intake Test meets all these requirements and if the reliability and validity of the nomogram established by Astrand and Ryhming (6) can be substantiated for Canadian children this test could become invaluable to physical educators.

According to Craig Taylor (87:204) ". . .intra-individual variation is the greatest source of test unreliability because in usual cases it serves only to detract from differentiating effectiveness of the test." By determining the intra-individual variation the predictive value of the nomogram may be established.

This information, when combined with that of other studies being conducted at the University of Alberta Physical Education Laboratory, should establish the usefulness of the Astrand-Ryhming nomogram for predicting the maximal oxygen intake of Albertans. If it is found reliable and valid widespread use of the test in Canada could ensue.

Limitations and Delimitations

1. It is assumed that the sample of Alberta youth used in this study is representative of the Alberta population of this age group.

2. The interpretation of the data is dependent on the validity of the principles underlying the establishment of the Astrand-Ryhming nomogram in its ability to predict maximal oxygen intake and that maximal oxygen intake gives an indication of "work capacity," a parameter associated with cardio-respiratory endurance.

3. Only one aspect of "physical fitness" is being investigated, that is, cardio-respiratory endurance.

4. Only one age group is being tested: high school students from grades X to XII inclusive. Children of the pre-high school age and adults are excluded although it is hoped that norms will eventually be developed for them as well throughout the entire nation.

5. Experimental error will undoubtedly be encountered.

6. Statistical procedures used will delimit the interpretation of the data.

Definitions

Physical work capacity. The ability of the individual to perform prolonged physical work, that is, the ability of the cardio-pulmonary system to take up, transport and give off oxygen to the muscle tissues for the performance of physical work (79).

Maximal oxygen intake. The rate of oxygen consumption, reached at a point below that of exhaustion, when the cardio-respiratory mechanisms can make no further adjustments to increasing work loads. In the Astrand maximal test, if the oxygen consumption at two consecutive work loads decreases or differs by less than 80 ml., the subject is considered to have reached his maximal oxygen intake (aerobic capacity).

Steady state. The period during which the pulse rate and other organic functions have adapted to the work load being performed. If the difference between two consecutive pulse rate readings taken one minute apart is less than five beats per minute, the subject is said to have reached a steady state (16).

Kilopond meter. One kp. is the force acting on a mass of one kilogram at the normal acceleration of gravity (16).

Error variance. That variance attributable to variable error in instruments, readings of the instruments and other mechanical sources.

Intra-individual variance. That variance attributable to biological variation in the functional status of the individual.

Inter-individual variance. That variance attributable to true differences between individuals.

CHAPTER II

REVIEW OF LITERATURE

Physical Work Capacity and Maximum Oxygen Intake

Astrand states (7:316):

> For maintaining a normal equilibrium in the different tissues under varying conditions an adequate blood supply will always be the most important pre-requisite. The type of fitness which is necessary for prolonged muscular exercise is well correlated to the individual's oxygen uptake capacity.

He has further commented (6,7) that aerobic capacity (maximal oxygen intake) is probably the best measure of a person's physical endurance, giving a good indication of physical fitness when divided by body weight. Rodahl (79:508) supported this concept by referring to maximal oxygen intake as, ". . .the best indication of physical work capacity. . . ." He defined "work capacity" as (79:500) ". . .the individual's total ability to perform prolonged physical work. For all practical purposes, this means the ability of the cardio-pulmonary system to take up, transport and give off oxygen to the muscle tissues for the performance of physical work."

Taylor et al. (89) lend further credence to the "work capacity--maximal oxygen intake" relationship by suggesting that it is generally agreed by work physiologists that the capacity to perform long continued physical work in a temperate environment is related to the capacity of the cardio-vascular-respiratory systems to deliver oxygen to the muscles (maximal oxygen intake), and Cumming and Danzinger (31),

Mill *et al.* (cited in 91) and Linde (68) agree.

With the foregoing ideas in mind, it will be useful to look at Mitchell's, Sproule's and Chapman's findings in 1958 concerning maximal oxygen intake. They state (73:541):

> Determinants of the maximal oxygen intake test have not been sufficiently clarified to enable one to accept the test as a measure of circulatory capacity with assurance. The term maximal oxygen intake must, itself, be viewed skeptically [in view of the fact that the actual value attained depends on the nature of the activity tested] .

Their data indicated that cardiac capacity is the primary determinant of maximal oxygen intake but that A-V oxygen difference makes a contribution of its own and that the maintenance of the partial pressure of oxygen in the arteries observed during heavy exercise on a treadmill is adequate evidence against the possibility that pulmonary factors, ventilatory or diffusive, determine maximal oxygen intake. This evidence indicates that the maximal oxygen intake which a normal individual can achieve is an index to maximal cardiovascular function provided pulmonary function is normal.

Literature is available, however, which proposes that "work capacity" and "maximal oxygen intake" are not precisely transposable terms. Taylor *et al.* (89:712) implied this by writing:

> If the investigator wishes to examine the work capacity, the subject walks until the pulse rate has reached 180 beats per minute. But if the investigator wishes to obtain the maximal oxygen intake and thus obtain a measure of cardiac capacity (always assuming normal lung function) the subject walks until he is exhausted.

Wahlund (91) felt that oxygen consumption did not in itself usually indicate the work capacity and might better be replaced by work intensity which he did in his study and was followed by several other

investigators (2,19,30). Instead of predicting maximal oxygen intake as the unit of work capacity he used a test developed by Sjostrand (85) which measured work capacity as the actual work load producing a steady state heart rate of 170 beats per minute.

According to Sjostrand (85:690):

> This working test is intended to ascertain the load at which the pulse rate starts rising rapidly or the pulse level reaches or exceeds the critical value where the heart minute volume decreases with rising pulse frequency. As is well known, the pulse frequency becomes rather constant in comparatively short time on a work which the organism is capable of performing without the respiratory and circulatory organs becoming insufficient, but is generally increased when respiration and blood circulation cannot longer adapt themselves to the energy consumption of the organism. The critical pulse level for adults will be about 180 beats a minute.

Astrand (12:59) criticized this procedure:

> It is obvious that all forms of extrapolation from submaximal work loads to a fixed heart rate, without regard to age, for the evaluation of the work capacity, or capacity for oxygen uptake during cycling, walking or running or a step test may be misleading, depending upon different maximal heart rates in different ages. This is valid regardless of whether one extrapolates to a heart rate of 170 (85,91) or continues the test until a heart rate of 180 (17).

If maximal oxygen intake is related to work capacity as the literature suggests, one would expect a high correlation between it and some actual work task. Taylor (87) used a time run on a treadmill to exhaustion criterion and found that in submaximal exercise oxygen consumption was chiefly a function of body weight ($r = 0.71$) and was only slightly related to physical fitness ($r = -0.20$) but in maximal work the relationship with weight dropped considerably and the correlation with the work capacity criterion increased considerably. Those subjects who could run the longest were those who had the greatest oxygen intake

in spite of no higher ventilation, heart rate, respiratory rate and blood lactate production. They could transport and consume oxygen at a higher rate. But he found that even if it was assumed that the greater oxygen consumption of the fitter subjects in maximal work indicated a greater circulatory reserve it correlated to the extent 0.55, explaining only 30 per cent of the variance. He explained this phenomenon by asserting that many other basic differences were in the neuromuscular mechanism and did not appear to be represented in the general circulatory and metabolic response. However, he did find a very high correlation between heart rate curve functions and the criterion ($r = 0.90$) indicating a pattern of cardiac adaptation to exercise.

Aerobic capacity, then, as a measure of work capacity has considerable support in the literature although some is with reservation. The method of calculating it, however, has been subject to considerable debate. Direct methods (73,88) have been devised which involve the analysis of expired air for carbon dioxide, oxygen and volume but the procedures and equipment do not make the tests practical for field work. In fact, Wahlund (91) expressed the opinion that maximal oxygen intake tests (such as direct measures of maximal oxygen intake) give an indication of the mental power of the individual and/or the maximum ability of the muscles to work under anaerobic conditions. Factors that determine or limit working capacity are neuromuscular, circulatory, respiratory and psychological and tests which determine the various factors during or after work of short duration give a conception of the individual's ability to adapt to work. He felt that there was no reason to

believe that there should be any simple correlation between the ability of rapid adaptation and the ability of performing comparatively heavy work during a steady state. Neither Borg and Dahlstrom (23) nor Taylor (87) found high correlations with maximal oxygen intake and performance criterions ($r = 0.45$ and $r = -0.20$ for submaximal work and $r = 0.55$ for maximal work respectively), although the validity of the criterion of the former investigators was dubious since they correlated maximal oxygen intake with the order of finish in a cross country ski race several months after having tested for maximal oxygen intake.

Submaximal tests of maximal oxygen intake such as the Astrand Predicted Maximal Oxygen Intake Test could prove to be extremely useful since it is conceded by most investigators that certain relationships between maximal oxygen intake and submaximal factors allow prediction of the one from the other.

Wahlund (91) found that provided the person tested was not at the point of exhaustion it was possible to get an estimate of oxygen consumption at the different loads without making a special determination. Oxygen consumption was indirectly estimated from work load within $\pm$ eight per cent in two-thirds of the cases.

Cumming and Danzinger (31:206) stated, since the oxygen pulse (quantity of oxygen carried per pulse beat) when plotted against work capacity gave a straight line relationship: "It would seem that the pulse rate method of determining work capacity in children is a valid one and that additional time involved in measuring oxygen consumption does not add a great deal of information."

Borg and Dahlstrom (23) supported this argument with their data which showed no correlation advantage in transposing the pulse frequencies to estimations of maximal oxygen uptake.

Astrand's reply to this extrapolation has been previously mentioned. Thus, the debate continues with the major differences between the two approaches to a submaximal work capacity test being in the test protocol.

Linearity of heart rate. Many investigators have reported a direct relationship between heart rate and oxygen consumption, some claiming linearity for all values of heart rate obtained and others, for portions of the curve (6,21,22,25,27,41,65,69,70,82,91). Since this is so, heart rate affords a means of predicting maximal oxygen intake and, in fact, this oxygen intake-heart rate relationship is one of the underlying basic assumptions of the Astrand-Ryhming Nomogram (6). However, Astrand (5), prior to establishing the nomogram, cautioned that heart rate gives only a rough conception of the individual's aerobic capacity.

Taylor, et al. (89), although stressing the fact that it is impossible to predict the difference in the actual amount of work represented by a difference in work pulse rate response to a standard task in two individuals because of the difference in slope of the work/pulse rate curve for different individuals states (89:717), ". . .measurement of the pulse rate response to a fixed submaximal work task or measuring the work required to produce a specific work pulse rate is in fact a measure of the capacity of the individual to carry on aerobic work

under environmental and physiological conditions at the time of the test." Oxygen consumption can also be predicted if the rate of work is accurately known and maintained constant.

The Astrand-Ryhming nomogram (6) as well as being based on the linearity of heart rate with oxygen intake depends on the linear relationship between heart rate and work load, also well supported by numerous investigators (5,19,31,82,91,92).

That the linear relationship between heart rate and oxygen intake does not hold at higher work levels has been suggested and verified by Wyndham (92) who criticized the nomogram on the basis that since the heart rate approaches a horizontal asymptote, in a diagram where heart rate is on the ordinate, there is a tendency to underestimate the maximal oxygen intake. Astrand (12) countered by claiming that the nomogram did not presuppose a linear function throughout the whole range of values but rather, was constructed empirically from data on heart rate and oxygen uptake during submaximal work and oxygen uptake actually measured, in experiments where this oxygen uptake reached a well-established level. It was not analyzed whether or not the heart rate increased with the oxygen uptake at the upper level. Since the occurrence of individuals with a non-linear type of curve was probably the same in the material which was used when constructing the nomogram as when applying it, that source of error was included in the given standard error of less than $\pm$ 10 per cent.

The basis of the construction of the nomogram for predicting maximal oxygen intake from submaximal work is extensively documented.

Astrand (12) emphasized, however, that this method of measuring only the submaximal oxygen intake or work load and heart rate would always be only an aid for a rough prediction of the aerobic work capacity. Direct measurement of maximal oxygen intake is essential if more exact information is desired.

Validity and reliability of predicted values from the nomogram compared with measured values. The Astrand-Ryhming nomogram (6) was based primarily upon the results obtained from twenty-seven male and thirty-one female well-trained subjects 20 to 30 years of age whose maximal oxygen intake was determined in maximal tests on the treadmill and bicycle ergometer and plotted against predicted values. The mean difference was 0.023 $\pm$ 0.059 litres per minute (l/min.) for males and 0.010 $\pm$ 0.051 l/min. for females. For two-thirds (2/3) of the cases the standard deviation was less than 6.7 per cent for males and 9.4 per cent for females. With a lower rate of work (600 kgm/min. for females and 900 kgm/min. for males) the respective standard deviations were slightly higher (14.4 per cent and 10.4 per cent respectively).

Eighteen well-trained males 18 to 19 years of age were given a step test and a running treadmill test to determine maximal oxygen intakes and these values were compared with those calculated using submaximal oxygen intakes and heart rates. The mean difference between the determined value by means of the step test and the calculated value was 0.006 $\pm$ 0.066 l/min. The standard deviation was less than seven per cent.

Wahlund (91), investigating men of varying fitness (athletes,

normal healthy men, people with heart and respiratory trouble), found a fairly constant mechanical efficiency when his subjects worked on a bicycle ergometer and he calculated their maximal oxygen intake indirectly from work load within a range of ± eight per cent in two-thirds of the cases.

In 1961, Hettinger, et al. (54) predicted the maximal oxygen intake of twenty-eight male subjects 20 to 30 years of age from work loads of 600, 750, 900 and 1,050 kpm/min. on a bicycle ergometer which produced heart rates ranging from 120 to 170 beats per minute. They found that the predicted maximal oxygen intake value of 2.62 l/min. was higher than the mean measured value of 2.38 l/min. This difference was significant at the .05 level of confidence, however, the correlation between the predicted and actual maximal oxygen intake was reported as being significant at the .01 level of confidence.

Two possibilities were suggested to explain the difference. The nomogram was established from the scores of well-trained individuals and might have given spurious values and it was also possible that the subjects involved in the study did not reach their maximal oxygen intake on the maximal test. Their mean value was 2.38 l/min., significantly lower than that of a selected group of Swedish men of the same age (4.11 l/min.).

In another group of nine Y.M.C.A. trained men age 56 to 68 years, Astrand and Rodahl (9), in 1959, predicted a maximal oxygen intake of 2.77 l/min. and measured 2.241 l/min., a difference of three per cent. In twenty-two well-trained men aged 23 to 48 years the mean predicted

oxygen uptake was 2.72 l/min. and the observed was 2.76 l/min., a difference of one per cent.

More recently, Rowell, et al. (81) presented data illustrating the effects of physical conditioning on the prediction of the maximal oxygen intake from submaximal pulse rates by comparing this prediction in successful athletes in excellent physical condition with a group of normal sedentary men. They then trained a group of sedentary individuals and compared their predicted values before and after training. Predicting aerobic capacity from the Astrand-Ryhming Nomogram, they found an under-prediction of the actual value in every case ranging from 5.6 $\pm$ 4.2 per cent for the athletes through 26.8 $\pm$ 7.2 per cent in the sedentary group to 13.7 per cent in the same sedentary group after conditioning them. These results show a marked trend toward improved prediction with increased physical conditioning.

De Vries and Klafs (35) studied a variety of predictive maximal oxygen intake tests on a bicycle ergometer comparing predicted and actual values and found a correlation of $r = 0.736$ with the Astrand-Ryhming Nomogram when the units were liters per minute. The Sjostrand Test in terms of kpm/min./kg body weight gave a correlation of $r = 0.877$. The authors concluded, since the nomogram required only one work load, that no advantage was gained in using the Sjostrand Test.

Baycroft (18), using forty-eight male subjects between the ages of 17 and 35 years found correlations of $r = 0.67$ and $r = 0.62$ when comparing Astrand-Ryhming Nomogram (6) values with Mitchell, Sproule and Chapman (73) measured values and Astrand Bicycle Test (5) measured

values respectively, reported in units of liters of oxygen per minute. With body weight partialled out the correlations dropped to r = 0.53 and 0.47 respectively.

Comparing three maximal oxygen intake tests and the Astrand-Ryhming predictive test Glassford (48) with twenty-four males between 17 and 33 years of age, found that the Nomogram gave maximal oxygen intake values equivalent to those obtained on the treadmill tests. The relationship between the nomogram values and any one set of values determined by a direct technique was as good as the relationship between the values of any two direct measures. Baycroft (18) arrived at a similar conclusion when he correlated the Astrand maximal bicycle test (5) with the Mitchell, Sproule and Chapman treadmill test (73).

Glassford's (48) mean maximal oxygen consumption values and his correlations are tabulated below followed by a summary chart of the literature just reviewed.

TABLE II:1

MEAN MAXIMAL OXYGEN CONSUMPTION VALUES

Test	Maximal Oxygen Consumption liters/min.	Ml./kg./min.
Mitchell, Sproule, Chapman	3.752 ± 0.467[a]	49.86 ± 5.65
Taylor, Buskirk, Henschel	3.758 ± 0.327	50.02 ± 4.43
Astrand Bicycle Ergometer	3.485 ± 0.402	46.31 ± 4.67
Astrand-Ryhming Nomogram	3.714 ± 0.837	49.30 ± 10.72

[a]Mean ± Standard Deviation. Source: Glassford (48:41).

TABLE II:2

CORRELATION COEFFICIENTS OBTAINED BETWEEN THE FOUR MAXIMAL OXYGEN INTAKE TESTS AND JOHNSON, BROUHA AND DARLING FITNESS SCORES
(Milliliters per minute per kilogram of body weight)

	MSC	TBH	AA	AP
JBD	.63	.65	.65	.79
MSC		.68	.65	.77
TBH			.74	.62
AA				.63

Source: Glassford (48:42)

TABLE II:3

CORRELATION COEFFICIENTS OBTAINED BETWEEN THE FOUR MAXIMAL OXYGEN INTAKE TESTS AND JOHNSON, BROUHA AND DARLING FITNESS SCORES
(Liters per minute)

	MSC	TBH	AA	AP
JBD	.68	.83	.68	.80
MSC		.75	.72	.78
TBH			.82	.72
AA				.65

Source: Glassford (48:42)

JBD - Johnson, Brouha and Darling Physical Fitness Test (58)
MSC - Mitchell, Sproule and Chapman Maximal Oxygen Intake Test (73)
TBH - Taylor, Buskirk and Henschel Treadmill Test of Maximal Oxygen consumption (88)
AA - Modified Astrand Bicycle Ergometer Test of Maximal Oxygen Uptake (5)
AP - Modified Astrand-Ryhming Nomogram for the Prediction of Maximal Oxygen Uptake (6)

TABLE II:4

SUMMARY OF LITERATURE REFERRING TO PREDICTED AND MEASURED VALUES OF MAXIMAL OXYGEN INTAKE

Author	Test	No. of Ss	Type	Max. O_2 Actual	Max O_2 Pred.	Mean Diff. From Pred.
Astrand-Ryhming	Treadmill & Bicycle	27M 31F	Well-trained 20-30 yrs			0.023±0.059 l/m 0.010±0.051 l/m
	Standard Deviation less than 6.7% for males, 9.4% for females. With lower work rate, 900 kgm/min for males and 600 kgm/min for females standard deviations were 14.4% and 10.4% respectively					
Astrand-Ryhming	Step test Treadmill	18M	Well-trained 18-19 years			0.006±0.066 l/m 0.020±0.058 l/m
	Standard Deviation less than 7%.					
Hettinger et al.	Bicycle Ergometer	28M	20-30 years	2.38 l/min	2.62 l/min	+0.24 l/min Sig. p=.05
Astrand & Rodahl	Bicycle Ergometer	9M YMCA 22M	56-68 years Well-trained	2.24 l/min 2.76 l/min	2.77 l/min 2.72 l/min	+0.53 l/min (3%) -0.04 l/min (1%)
Rowell et al.	Treadmill	10M 17M 12M 10M	endurance athletes sedentary normals (before training) (after training) Athletes Sedentary			-5.6±4.2% -26.8±7.2% -13.7% Sig.Dif.(P=.01) bet. prediction of athletes & sedentary subjects.
de Vries	Bicycle	16M		r=0.736 re. l/min		
Glassford	Bicycle Treadmill M.S.C.	24M	Active 17-33yrs r=0.65	3.485±0.402 l/m 3.75±0.47 l/m r=0.78	3.71±0.84 l/m 3.71±0.84 "	+0.23 l/min -0.04 l/min
Baycroft	Bicycle Treadmill M.S.C.	48M	Active 17-35 yrs	3.43±0.46 l/m r=0.62 3.67±0.51 l/m r=0.67	3.66±0.78 " 3.66±0.78 "	+0.24 l/min -0.01 l/min

Borg and Dahlstrom (23), in 1962, studied seventy-eight former male forest workers aged 20 years, enlisted in the army, in an attempt to investigate the reliability and validity of some different measurements of importance for physical work capacity. Although their test-retest techniques are subject to criticism and their validity criterion is debatable their intra-test reliabilities are informative. They tested these men on a bicycle ergometer at 600, 900, and 1,200 kpm/minute for six minutes at each level and recorded heart rates after working two, four, and six minutes and respiration rates after three and five minutes. The first test was administered in the summer of 1957 and the re-test in the spring of 1958 so it is not unreasonable that the test re-test correlations of physical work capacity might be low. Their criterion for the validity of the Astrand test as a measure of work capacity was set upon the results of a twenty mile ski race which was held between one and two months before the second test. Changes in the fitness level of the subjects could easily have occurred in this time interval.

The intra-test reliability for the heart rate was calculated for two work loads and was found to be quite high. At 900 kpm/minute the reliability between values at the fourth and sixth minute for the first test was 0.97 and for the re-test 0.98. At 600 kpm/minute for the same times r = 0.90 and between the second and fourth minutes, r = 0.88 and 0.91, in the first and second tests respectively.

The test re-test correlations for heart rates at 600 kpm/minute were between 0.50 and 0.60 and at 900 kpm/minute, between 0.60 and 0.70.

The correlations between the Astrand values within the test were r = 0.83 and r = 0.79. These correlations must be considered high as they were based to a certain extent on the assessment of two power levels and could therefore be compared with the "corresponding" correlations between the pulse rates at two power levels which were r = 0.78 and r = 0.83.

The test re-test correlation for the Astrand values at the higher work levels was r = 0.71 and the averages of both power levels, r = 0.67. But again, it must be emphasized that several months elapsed between tests.

The validity coefficients between the criterion and the Astrand values from the highest work levels were r = 0.38 and r = 0.45. The weaknesses in the criterion are, however, evident.

From the studies available concerning the reliability and validity of the nomogram the values seem to be acceptable for practical purposes.

Certainly several other important questions arise as to the acceptability of the Astrand Predicted Maximal Oxygen Intake Test and these will be commented on in the following reviews of literature.

Wahlund (91:18) stated:

> Tests of physical working capacity should meet the prerequisites listed below.
>
> 1. A large number of muscles must be involved. . . .
> 2. Different and sufficiently heavy loads must be used to make it possible to estimate the maximal steady state level of the subject in question.
> 3. . . .Most subjects must attain a steady state during moderate loads. Their working time must not be too long.

Advantages of Using a Bicycle Ergometer

1. It is practical for laboratory work since it occupies very little space and is easy to handle.

2. Work can be exactly reproduced.

3. Large numbers of muscles are involved.

4. Oxygen consumption is directly related to work load, and the mechanical efficiency determined on various individuals shows comparatively slight differences.

5. It is thus possible to make direct comparison between different subjects and between the reactions at different loads as there are few extra movements not taking part in the production of work output as compared with running and walking where a static component is involved.

6. Various determinations are easily made during work.

7. The work intensity can be adjusted so that the subject is not overloaded.

8. Hydrostatic changes in blood distribution may be expected to play a comparatively slight role. On the assumption that the subject to be tested has had some opportunity to practice cycling this type of work may be preferred to any other.

Wyndham (92) suggested that in cycling the subject used mainly the lower extremities and lower trunk muscles at low work levels and for this reason might give a less valid reflection of his maximal oxygen intake than at a task involving a large proportion of both limb and trunk muscles.

Mechanical efficiency. Newton (77) in 1963 found that when comparing several methods of determing oxygen consumption (Balke Test, Cureton Test, Bicycle Ergometer Test and Treadmill Run) the bicycle ergometer values were consistently lower than those obtained with either the Balke or the Treadmill run. This he attributed to additional muscular development and training required to perform well on a bicycle.

This comment would indicate that the mechanical efficiency of different individuals on a bicycle is quite variable. In order to accurately compare individuals with respect to work capacity, it is essential that the mechanical efficiency of the task shows a relatively small standard deviation since, according to Astrand (7:315): ". . . in determining fitness for endurance work mechanical efficiency, technique or skill must be regarded as another decisive factor."

Net mechanical efficiency has been calculated using the following relationship (5):

$$\text{Net Mechanical Efficiency} = \frac{\text{work performed} \times 100}{(\text{total energy}) - (\text{basal energy})}$$

Basal metabolism can be found in Mayo Foundation Standards and oxygen intake can be converted to calories of heat.

The caloric equivalent of oxygen = 4.90 calories per liter.

Astrand states (7:315):

> In simple movements where large muscle groups are working it has been found that mechanical efficiency shows only small individual variation. During work on a bicycle the standard deviation in mechanical efficiency was $\pm$ 8 percent of the value found for athletes, normal healthy men and people with heart or respiratory trouble provided the work level was adapted to the capacity of the individual. Men and women have roughly the same mechanical efficiency when cycling but the more complicated the exercise the greater are the individual variations. Efficiency can be increased by training.

Wahlund (91) found that efficiency increased with increasing work load with values of 20.8 per cent at 600 kgm/min., 22.9 per cent at 900 kgm/min., and 24.0 per cent at 1,200 kgm/min., for 370 of the subjects commented on above by Astrand.

Taylor, et al., in 1950 (86), using nineteen boys, 7 to 15 years of age found the following net efficiencies for the different age groups:

	Net Efficiency	
	(gross minus basal metabolism)	(gross minus metabolism while sitting in a chair)
2 - 9 years	18.4 per cent	24.6 per cent
9 -11 years	22.8 per cent	30.8 per cent
12 -15 years	17.9 per cent	23.7 per cent

Astrand (5), using a work range between 1,800 and 2,400 kgm/minute for males and between 1,200 and 1,650 kgm/minute for females, found that the values of mechanical efficiency differed less than 0.1 per cent from the means of the entire material. The efficiency of the males was very constant between 23.3 and 23.7 per cent and of females 22.5 per cent at 600 kgm/minute and 23.1 per cent at 900 kgm/minute. The individual net efficiency was approximately 23 per cent, independent of sex.

Bengtsson (19) noted that the net mechanical efficiency for children was somewhat less than that for adults and Rodahl (79), comparing Philadelphia boys and Swedish boys, age 14 years, found that the mechanical efficiency was not significantly different.

Time Required to Attain a Steady State

Some difference of opinion exists among investigators as to the time required for a person to adjust to a submaximal work task. This influences directly the procedure in using the Astrand Predicted Maximal Oxygen Intake Test.

Liljestrand and Stenstrom (cited in 91) in 1922 stated that oxygen consumption reaches a constant value after one to two minutes if the work load is not too high. Few of the more recent studies support this.

Lundgren (70), who did considerable work with this problem, found that adjustment to a given submaximal work task was complete in from three to four minutes.

Cumming and Danzinger (31) suggested that oxygen consumption during the first minute of submaximal work increased rapidly to reach a plateau by the end of the second minute. They found that for submaximal work loads the pulse rate was usually constant from the second to the sixth minute of each exercise period and it was only when near maximum work loads were undertaken that a rise of over eight beats per minute was observed. This appears to be contradictory with Astrand and Saltin's findings (13) that a steady state could be attained in one minute only with extremely heavy exercise. They feel that actual steady state values for lower work loads were found between the fourth and eighth minute.

Borg and Dahlstrom (23) claimed that an increase in reliability was found with longer periods of cycling of two, four to six minutes.

Higher work loads also tended to give higher reliability.

Thus the prescribed six minute ride in the Astrand submaximal test probably allows time for body adjustment to the work load and the attainment of the steady state.

The Effect of Emotion on the Working Pulse Rate

Since the main purpose of the Astrand Predicted Maximal Oxygen Intake Test is practicality, its major use would probably lie in the field away from the research laboratory. Naturally, experimental conditions are impossible to control as accurately here as in the confines of the laboratory. One of the major problems involved is the apprehension most subjects feel because of unfamiliarity with the test or what may be expected of them along with uncontrollable physical disturbances. Bengtsson (19) feels that it is likely that such conditions will be less marked during continuous and heavy work, and indeed, at submaximal intensities it seems questionable whether the mental factor will have any significance at all (72,85).

Astrand (10) asserts that the heart rate and related functions of importance for the oxygen uptake and transport are definitely regulated within very narrow limits determined by the work output and fitness of the subject and are apparently, to a high degree, resistant to changes in the mental state of the subject.

On the other hand, Taylor, et al. (89) cite evidence suggesting that emotion does play a role in affecting work pulse rates. In a treadmill walking study where men were assigned to walk at 3.5 m.p.h. on a ten per cent grade for six, ten-minute periods interspaced by ten

minutes of rest, one of the subjects during the third period stumbled getting off. His heart rate which had been approximately 130, 130 and 119 beats per minute, respectively, for the first three walks immediately rose to about 155 and remained there for the next three walks. The next morning his pulse rate was 150 for the first walk, and gradually decreased, reaching 130 again by the fourth walk and levelling at about 125 beats per minute during the last two walks.

The same authors observed that submaximal pulse rates were significantly higher during the subject's first contact with the test than on subsequent test periods and that the only way of recognizing the effect was by the time consuming method of repeating the procedure.

Rowell, et al. (81) compared submaximal pulse rates of seven subjects who performed with catheters inserted into their brachial artery with those of a standard group. Before training there were no significant differences between the groups. After training, submaximal pulse rates were elevated above those observed during standard conditions when the subjects performed under the stress of catheters. There was six per cent ($P = 0.001$) greater underestimation of maximal oxygen intake using the nomogram under the added stress of catheterization. The observed maximal oxygen intake was unchanged.

Similar effects were found with athletes. In every case but one, using approximately ten subjects, elevation of pulse rates during work requiring 60 per cent of the maximal oxygen consumption resulted in large depressions of predicted maximal oxygen intake.

Taylor, et al. (89:708) state:

> It is evident that the initial contact with a work test can result in significant increases in submaximal work pulse rate. . . . It is clear that the submaximal pulse rate-work rate relationship can be displaced to the left without an important rise in the maximal pulse rate.

Emotion, therefore, can cause a low prediction of the work necessary to increase pulse rate to a given level according to these authors.

In field-testing situations, however, when large numbers are to be tested, placing a premium on time, it is impossible to orientate the subjects and put them completely at rest. A solution to the problem has not yet been proffered.

The Effect of Intra-Individual Variation

Krogh and Lindhard (65), in 1917, showed that the rate of increase of pulse rate is a function peculiar to each individual and that it may or may not be the same as that of another person.

In 1944, Craig Taylor (87:201) conducted a detailed study ". . . to compare responses of a group of subjects to submaximal and maximal work in repeat experiments to compare intra-individual with inter-individual variation and to point out some essential differences in fitness as tested in these types of experiments."

The criterion of fitness was a time run to exhaustion which he claimed was (87:202) "the only defensible a priori criterion of the fitness of a man for heavy physical exercise. . . ." Subjects of the group tended to repeat their times in a duplicate run having no knowledge of the previous score. The test-retest reliability coefficient was 0.95.

According to Taylor, sources of variation in physiological

measurement contributing to the total variation (S_T), are test-retest variation (S_D) composed of variations in the method (S_M), Intra-individual variation (variation within the individual S_P), and Inter-individual variation (S_G).

The estimation of the method and test-retest variation was derived from the relationship

$$S.E. = S \sqrt{1-r_{11}}$$

where

S.E. is the standard error of the measurement.

S is the average standard deviation for two series

r_{11} is the correlation between the two series.

S_D, S_M, S_P and S_G were all calculated from the following relationships. S_D was readily accessible, being the between trial variance. S_M was measured.

$$S_P = \sqrt{S_D^2 - S_M^2} \qquad S_G = \sqrt{S_T^2 - S_D^2}$$

It was found that the variance due to method was much lower than the other variance but that the intra-individual variation was large. Since the test-retest reliability is an inverse function of the combined variance of method and that within the individual, the latter is by far the greatest source of test unreliability.

Taylor said (87:204):

> . . .Intra-individual variation. . .is the greatest source of test unrealibility because in usual cases it serves only to detract from the differentiating effectiveness of the test. Such intra-individual variation, unaccompanied by any tangible change in the fitness of the individual must at present, be considered an obstacle to the reliable determination of the prevailing fitness of the individual.

When these principles were applied to the data it was found that in terms of per cent of total variance (S_T) with respect to heart rate at submaximal efforts the method variation (S_M) accounted for 0.6 per cent (that is, $\frac{SM}{S_T}$), intra-individual variation (S_P) for 21.8 per cent (that is, $\frac{S_P}{S_T}$) and inter-individual variation (S_G) for 77.6 per cent (that is, $\frac{S_G}{S_T}$).

For oxygen consumption at submaximal efforts the values were 0.3, 40.2 and 59.5 per cent respectively. Whan maximal work efforts were investigated, the heart rate values were 1.4, 17.6, and 81.0 per cent and oxygen consumption 0.1, 30.4, and 69.5 per cent respectively of the total variance. It is therefore readily apparent that intra-individual variation is diminished in the transition from submaximal to maximal efforts.

Morford (75:2) has the following to say about the reliability coefficient:

> The gross score of a person on a test consists of "T" or the ability of the person which is relatively stable as long as the test measures the same thing, and a second component "E" or error. The obtained score does not necessarily equal "T".
>
> $X_i = T_i + E_i$
>
> where:
>
> X_i is the score of subject i on a test
>
> T_i is the true score of this person
>
> E_i is the error component of the same person.
>
> Algebraic relationships, of course, hold here.
>
> Derived from this equation is the relationship $\sigma_x^2 = \sigma_t^2 + \sigma_e^2$

or the variance of the observed score equals the sum of the variance of the true score σ_t^2 and the variance of the error component σ_e^2. Fundamentally σ_e^2 is the degree to which an individual's rank in the group of observed scores would probably deviate from his ranking in the true score.

σ_e^2 can be further broken down in measurements of a physical nature. This breakdown is a combination of the "true" error of measurement and intra-individual variation.

Taylor's (87) comments on the significance of intra-individual variation on the usefulness of a test have already been noted. In Morford's (75) material the point is made that by increasing the number of trials on a particular discrete performance (for example, a submaximal bicycle ergometer ride) from which the mean is computed and used as the score for the individual, a decrease in the sampling error of the individual's performance about his own mean or true score may be achieved.

The reliability coefficient is merely the measure of the ratio of individual differences to total variation in test scores $(\frac{\sigma_t^2}{\sigma_x^2})$.

By determining error in measurement and the mechanics of a test the variation within and between individuals may be calculated. Using statistical techniques the number of test trials required to raise the reliability coefficient to acceptable levels can be determined. This could be of considerable value in arriving at the usefulness of a submaximal test such as the Astrand Predicted Maximal Oxygen Intake Test.

Physical Work Capacity and Height, Weight and Surface Area

Of the studies reviewed, only Adams, et al. (2) reported a low correlation between work capacity and height, weight and surface area. The work capacity was defined as that work load producing a reasonably steady state at a heart rate of 170 beats per minute ($P.W.C._{170}$). The correlation coefficient for country girls aged 10 to 12 years in Sweden was 0.66 and 0.69 and for the other age groups, lower than this.

Cumming and Cumming (30), in 1963, using the same work capacity criterion as above with 200 subjects aged 6 to 16 years found a correlation coefficient with boys of 0.865 for height, 0.897 for weight, and 0.904 for surface area. The relationship was somewhat lower for girls.

Gallagher and Brouha (45) reported a greater correlation between their fitness index, based on pulse rate, and surface area than with age but Bengtsson (19) using the $P.W.C._{170}$ criterion states that both in children and young people up to age 20 years the body weight seemed to be, in general, the relative factor of choice. He found that girls in the 15 to 20 year age group showed a low correlation of exercise intensity to body weight but a somewhat higher one to surface area. However, having regard to the fairly high weight correlation in women between ages 21 and 40 years it seems plausible to assume that correlation with body weight is justified even in females aged 15 to 20 years. In males between 21 and 40 years both body weight and surface area correlations were very low. These contrast with high correlations for the same variables in 15 to 20 year old males.

The rise in oxygen consumption he found to be independent of weight. This may suggest that for valid comparisons of oxygen consumption

between individuals the pre-exercise value should be determined since any observed differences may be a result primarily of this initial difference.

Astrand, in 1952 (5), found a correlation coefficient between oxygen consumption and body weight for males or r = 0.98, for females below 88 pounds, r = 0.96 and above 88 pounds, r = 0.86. The values were derived from scores of 227 subjects between the ages of 4 and 33 years, about half of them male and half female.

Adams, et al. (1) , in their study, found that the best correlation was achieved between work capacity as measured by the Sjostrand Test and the logarithm of the surface area (r = 0.81 for males and r = 0.80 for females, ages 6 through 14 years). They used logs to make the regressions linear and the variability homogeneous and found correlations between work capacity and the log of body weight to be r = 0.77 and r = 0.81 for girls and boys respectively and between work capacity and the log of height to be r = 0.76 and r = 0.83.

Taylor (87) showed that in submaximal exercise the correlation between oxygen consumption and weight was 0.71 and for maximal work efforts 0.43. This indicated that in submaximal work, oxygen consumption was chiefly a function of body weight and only slightly related to fitness (r = -0.20) but in maximal work the relation with weight dropped markedly and the correlation with the fitness criterion rose considerably.

Age and Sex Variation in Work Capacity

It is generally agreed that there is a gradual rise in maximal work

capacity with age (2,5,19,30) and that males generally have a larger work capacity than females.

Cumming and Cumming (30) and Adams, et al. (1) reported a greater work capacity in males from the age of 6 years on but most other authors feel that the divergence comes with puberty (5,19,29,57,79).

Astrand (4) and Bengtsson (19) found that up to the age of 15 years there were no significant sex differences in work capacity but after that age males scored about 30 per cent higher than females. The difference was significant at the .01 level. Dane (33), Morse (76), and Adams (1) noted major variation to be common in puberty and Jokl (59) recorded some retardation of the mounting work capacity during this period.

Cullumbine (29) supports Jokl's findings in his observations of 7,000 Ceylonese from the ages of 10 years up and recorded no significant variation in male age groups before adolescence, with respect to the heart rate response to moderate exercise, but that there was a sudden drop in the fitness level according to this criterion at age 14 years. The 14 to 16 year fitness index remained constant but below the pre-adolescent level. This was followed by a rise in the value to a maximum at the age of 21 to 25 years.

The pattern for females was similar with the peak occurring at ages 31 to 35 years but they showed a steady decline with age in an endurance criterion which was accelerated by the onset of adolescence. The index at 14 years was significantly less than that at 10 years ($p = 0.001$) and continued to decline. Males responded to this criterion

similarly showing a slight rise in the index at age 20 years then a steady fall.

Astrand (5), in a study in 1952, involving 112 females and 115 males, regarded the lower values of oxygen intake for girls age 10 - 12 years either as early secondary sex characteristics or as slightly unrepresentative material. The youngest subjects ages 4 to 6 years had definitely lower oxygen intake capacity than older subjects but it could not be decided whether they gave up too early or had physiologically lower capacities.

Boys ages 7 to 11 years and girls, ages 7 to 9 years reached practically the same oxygen intakes per kg. body weight as adult men (boys 7-9 years, 56.9 ml/kg; adult men, 58.6 ml/kg.). This is a three per cent difference. On the other hand, the younger subjects had a higher basal metabolism. The 7 to 9 year old boys, in attaining their maximal oxygen intake produced a 9.4 fold increase while men increased 15.7 times their basal rate.

For boys, no decrease in maximal oxygen intake per kg. body weight was found during puberty. Even a tendency toward higher average values for the subjects 14 to 15 years of age as compared to the next highest or next lowest age group was observed. This was in opposition to the results obtained by Robinson (78) and Morse, et al. (76) who found lower oxygen intakes during puberty.

The decrease in aerobic capacity per kg. body weight from about age 10 years on in females, widening the difference between them and males, was attributed to sex maturity, with the resultant fat accumulation in females thought to be a factor.

The changes in aerobic capacity at puberty might have been a result of hemoglobin changes since a high correlation (r = 0.97), was found between total hemoglobin and maximal oxygen intake where the male and female values followed the same regression curve to a large degree. The quantity of hemoglobin was similar for boys and girls up to 14 years of age (7-9 years, 220 gms.; 12-13 years, 370 gms.) but after that age their values separated and attained different levels (males, 700 gms., females 500 gms., representing about a 30 per cent difference). This was roughly the difference noted for maximal oxygen intake. The hemoglobin quantity with respect to body weight was similar for boys and girls up to 12 years (7.5-8.0 gm. per kg.). Older girls showed no great change in their values but in the case of boys an increase took place and they reached a new level at 14 to 15 years (10 gm/kg). The difference between males and females was approximately 20 per cent, also corresponding to differences in aerobic capacity per kg. body weight.

Blood volume had nearly the same relation to sex and age as hemoglobin but the difference was only 13 per cent.

Astrand (5) reported the greatest individual variation occurring from the ages of 12 to 15 years although that of adults was considerable as well.

Bengtsson (19) supported this to a degree but found the largest standard deviation in children below ten and relatively small variation in adults. From the ages of 5 to 14 years the work capacity at a given heart rate rose steadily. Compared with a 13 or 14 year old, a child of 5 or 6 had a work capacity 37 per cent of the former; ages 7 to 9,

50 per cent and ages 10 to 12 years, 83 per cent. When compared to adults the values were 20, 28 and 44 per cent, respectively.

Durnin, et al. (39), in 1956, showed a falling off in the circulatory and pulmonary function in elderly men indicated by the falling off of mean values of oxygen consumption and an increase in energy output when compared to younger men. This was more marked as the severity of the work increased.

CHAPTER III

METHODS AND PROCEDURES

Field Study

One thousand twenty-four subjects were tested on the Astrand Predicted Maximal Oxygen Intake Test and were selected randomly from all of the Protestant and Catholic Secondary Schools in each of the towns and cities used by the Federal Government in its stratified labour force sample in the Province of Alberta. The sample of the cities and towns to be visited was drawn up by the Edmonton Branch of the Dominion Bureau of Statistics, and being based on socio-economic, geographic, industrial and population density data, was deemed to be representative of the entire Alberta population. Forty-four towns and cities were selected and as the rural children attended town schools this section of the population was not excluded (see Appendix B).

Three per cent of the students in Grades X to XII were randomly selected by means of a table of random numbers and class enrolment sheets provided by the schools involved.

Of the 1,024 students tested, 499 males and 417 females were analyzed statistically for differences in various parameters. One hundred eight subjects were discarded, before the data was analyzed, for various reasons, including incomplete information, mechanical difficulties with the bicycle ergometer or other equipment, errors in the work load setting and other unavoidable problems, all of which, the investigators felt, invalidated the trial. Because of administrative

difficulties with field testing of this magnitude it was impossible to retest these people.

In all analyses conducted on an age basis, 488 males and 410 females were used. These subjects were between the ages of 15 and 19 years inclusive for both sexes since it happened, through random sampling, that for the males only six 14 year olds, four 20 year olds and one twenty-one year old were tested and for the females four 14 year olds, two 20 year olds and one 21 year old were tested. It was felt that because of the small numbers these subjects could not be considered representative of their age group and were therefore left out of the age group comparisons. They were included, however, in analyses where the subjects were grouped together regardless of age since all of their scores lay well within the range of scores of the other age groups and hence probably had little effect on the means used in the various analyses.

All ages were recorded as of the time of testing and the age groups referred to in the study were derived as of the first of the month, that is to say, the 15 year old age group contained those individuals 15 years, 0 months to 15 years, 11 months old as of the date of testing. The remaining age groups were established, of course, in the same way.

Table III:1 is a tabulation of some of the characteristics of the subjects used.

Any person selected in the sample who was not allowed to take physical education for medical reasons was not tested and was replaced by an alternate subject also randomly selected. Students who were

TABLE III:1

SOME CHARACTERISTICS OF THE SUBJECTS TESTED

Age (yrs)	n	Weight (kgm)	Height (cm)	Age (months)
MALES				
15	62	60.12 ± 8.70[a]	172.9 ± 7.35	
16	146	64.23 ± 8.71	174.5 ± 6.84	
17	162	65.82 ± 9.32	175.4 ± 6.90	
18	82	68.93 ± 9.86	176.9 ± 7.22	
19	36	68.11 ± 11.36	176.8 ± 8.63	
15-19	499	65.24 ± 9.66	175.2 ± 7.25	206.5 ± 13.7
FEMALES				
15	78	54.28 ± 7.22	162.3 ± 5.66	
16	152	55.34 ± 7.39	163.3 ± 6.45	
17	132	55.04 ± 7.47	162.6 ± 6.38	
18	39	57.51 ± 8.07	163.5 ± 5.21	
19	9	56.06 ± 10.62	161.2 ± 6.77	
15-19	417	55.24 ± 7.52	162.8 ± 6.19	202.1 ± 11.7

[a]Mean ± standard deviation.

selected but who were not at school on the day of their test were replaced by alternates as well. As far as the investigators could ascertain by questioning the subjects were in good health although a few mentioned that they had colds.

Permission to visit the schools was secured from the Department of Education, from the local School Board Superintendent and from the Principal of each school in the sample.

Testing in the schools commenced on April 14, 1964, and was completed early in June, 1964.

The experimentors were three graduate students at the University of Alberta who were well-trained in the administration of the test.

The Astrand Predicted Maximal Oxygen Intake Test

The subjects, upon entering the testing area, were required to complete a data sheet with the help of one of the testers. A copy of this sheet is included in Appendix F. The height and weight of all subjects was measured and they were asked their age and birth date, whether or not they smoked, their place of residence (farm, country, town or city using a population criterion not pertinent to this study), and the type and frequency of recent participation in physical activity. The test procedure was outlined together with the purpose of their riding the bicycle ergometer. The subject then mounted the apparatus. The seat and handlebars were adjusted to the subject's comfort and a pre-exercise heart rate was taken. An electric metronome was started and set at 100 beats per minute which established a pace of 50 pedal revolutions per minute. When the subject was in time with the beat the work load was adjusted to a level which the experimentors estimated would produce a steady state heart rate between 120 and 170 beats per minute.

The pulse rate was taken by palpation at the carotid artery fifteen seconds before the end of each minute by recording the time on a stop watch for 31 beats to be counted (that is, 30 beats starting at zero). This time was converted, by means of a table of scores, to beats

per minute. If the steady state reached was below 120 beats per minute by the end of the fourth minute the work load was increased until an acceptable steady state was reached. The test required a pedalling time of from six to nine minutes. A steady state was said to have been reached if the pulse rates at the end of the fifth and sixth minutes of work did not differ by more than five beats per minute. The mean of these two pulse rates was then compared with the work load in kilopond-meters per minute and the maximal oxygen intake was predicted from the Astrand-Ryhming nomogram (6).

Secondary problem. Thirty secondary school males and twenty-seven secondary school females in grades X to XII were tested during July and August of 1964. Where possible, students who had been randomly selected from Edmonton schools for the main problem and had been previously tested on the submaximal test in the spring were used in this study.

Twenty-two boys and twenty girls had been tested before. The remainder were friends of those tested or the children of the university staff. Each subject was given a medical examination by a doctor at the University Hospital before being allowed to participate in the test.

These subjects were tested on two days not more than one week apart, half of them first on the Astrand Predicted Maximal Oxygen Intake Test as described above and then on the Astrand Maximal Oxygen Intake Test described below. The other half of the subjects began with the maximal test and finished with the predicted test. Which order was

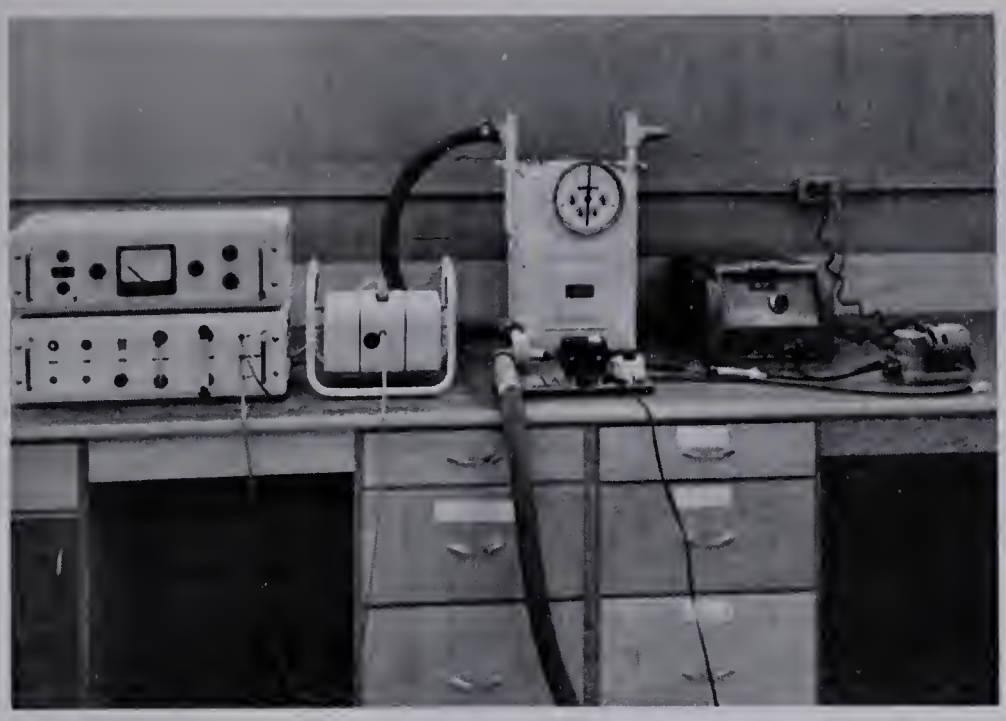


FIGURE III – i Godart CO_2 Analyzer, Volume Meter, Beckman E–z O_2 Analyzer

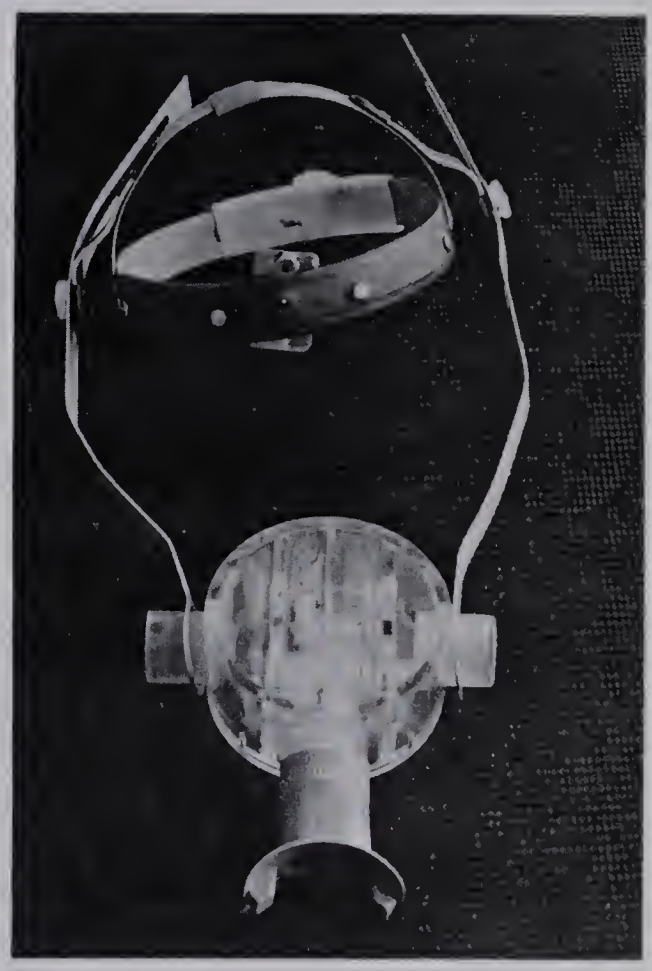


FIGURE III – ii Modified Otis McKerrow Valve with light weight head gear.

FIGURE III – iii Monark GCI Bicycle Ergometer

followed was decided upon somewhat arbitrarily depending partly on how much time the subject could afford to spend on the first test day and partly on how many consecutive subjects had performed either the predicted or the maximal test first at any given time. This "alternating" of which test was administered first was done to avoid any "familiarization" effect that initial testing on one test or the other may have had on the heart rates of the subjects.

Two tests were given so that test-retest reliability of the predicted maximal oxygen intake from steady state heart rates at submaximal work efforts could be established and so that the predicted maximal oxygen intake could be compared with the value actually found during the maximal test. The predicted value was based on the steady state heart rate, as described above, reached at the end of the first work load attempted during the maximal test. The submaximal tests differed from those administered in the schools only in so far as heart rates were recorded on an electrocardiograph as well as by palpation so that a reliability coefficient for palpation technique could be established from low through high work intensities.

The Astrand Actual Maximal Oxygen Intake Test

Upon entering the laboratory the subject was weighed and his/her height was measured. The subject was then briefed as to the test procedure while he/she was connected with the leads to a Sanborn Twin-Viso Recorder Model 60-1300, Cambridge, Massachusetts. The electrodes were applied to both upper arms of the girls on the dorsal surface when the subject was holding the handle-bars and on the chest immediately below

FIGURE III – iv Calibration of Monark Bicycle using 2 kilogram weight.

FIGURE III – v Astrand–Ryhming predicted maximal oxygen intake test. Note: palpation heart rate technique, placement of electrodes for female subject, metronome, electrocardiograph.

the nipples of the boys. The ground lead was applied to the forehead of both boys and girls.

Immediately prior to the commencement of the test a pre-exercise heart rate was recorded.

The metronome was set at 100 beats per minute and the subject commenced pedalling at this rate (50 pedal revolutions per minute). The work load was set at 300 kpm/min. for the girls and 600 kpm/min. for the boys and the subject continued to pedal for six minutes. Heart rates were recorded both by palpation and by E.C.G. during the last fifteen seconds of each minute. Just prior to the beginning of the sixth minute, the subject was told to place the mouth piece of an Otis-McKerrow two-way breathing valve in his mouth and to put a nose clamp on his nose. Expired air was then collected in a Douglas Bag from the fifth to the sixth minute and analyzed for percent oxygen, percent carbon dioxide and volume from which measures, the oxygen consumption for that work level could be calculated.

After pedalling for six minutes, the subject rested on the bicycle for five minutes. The work load was then increased by 300 kpm/min. to 900 kpm/min. for the boys and to 600 kpm/min. for most of the girls although for some of the subjects who had difficulty finishing a work load the increase was 150 kpm/min. for the next six-minute ride, the same procedure as that described above being followed. This method of six minutes of pedalling and five minutes of rest with an increase of 300 kpm/min. or 150 kpm/min. at each work level was continued until two consecutive oxygen consumption values did not differ by more than 80 ml., the criterion used by Astrand (5), or until a value was lower

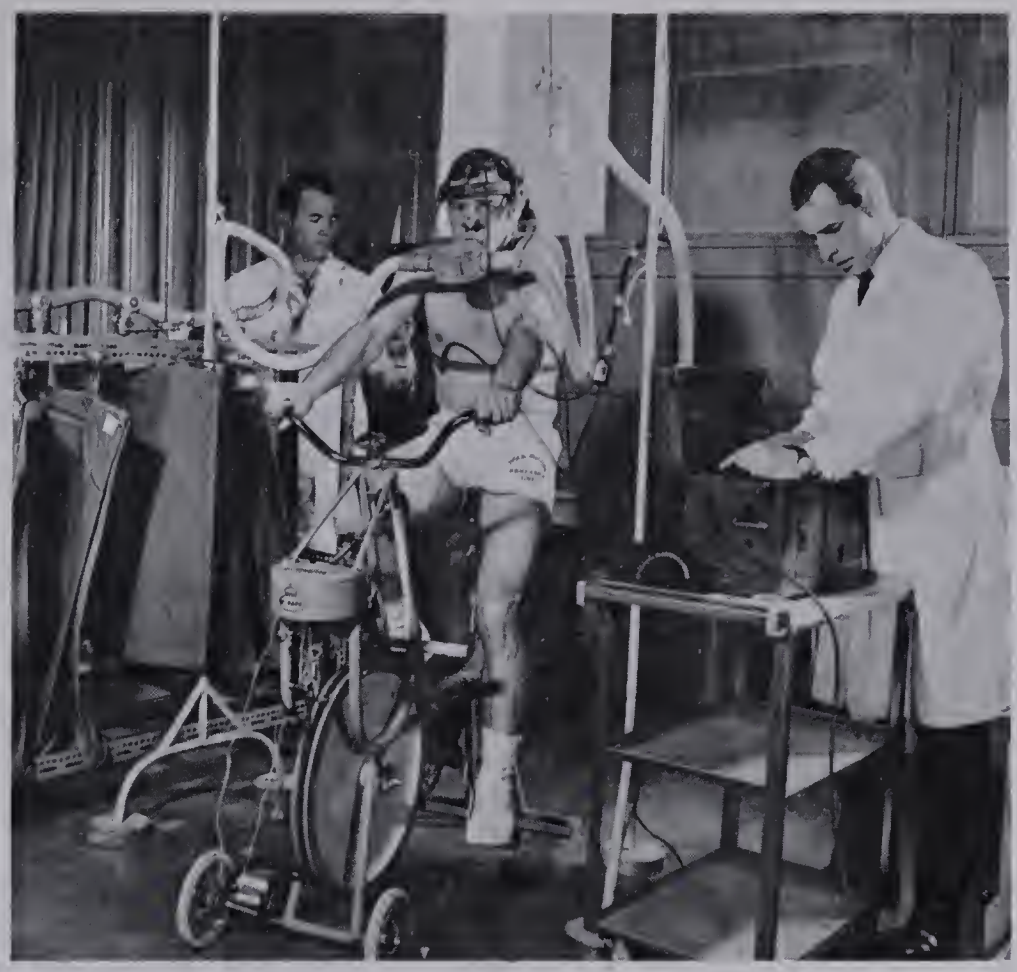


FIGURE III – vi Astrand actual maximal oxygen intake test. Note placement of electrodes for male subject.

FIGURE III – vii Palpation heart rate technique during Astrand actual test.

than the preceding one. The subject then rested five minutes as before, and pedalled one additional work level to see if any further change in his "maximal" oxygen intake had occurred.

In the event that a subject was unable to complete six minutes of a work load the mouth piece was inserted early and a minimum sample of fifteen seconds of expired air was collected.

Calibration of equipment used. Between day variance in a test-retest design is attributable to the sum of the day by day physiological and psychological fluctuations in an individual which affect his performance and variable mechanical error in the instruments used. The former is the within or intra-individual variance and the latter is termed error variance. It was felt that measurement error would be found predominantly in the capnograph, the oxygen analyzer, the volumeter and the work load setting on the bicycle.

The oxygen percentage in the nitrogen used to calibrate the oxygen analyzer was checked on a micro-scholander gas analyzer as was the carbon dioxide percentage for the calibration of the capnograph (see Appendix E).

The volumeter was checked against two Tissots and a correction factor was established which also accounted for volume losses due to the sample of gas used in the oxygen analysis (see Appendix E).

The calibration of the Monark bicycle ergometer was checked using a set of standard masses as described by Astrand (16:3) and was found to be accurate within less than one per cent of the standard weight values over the tension ranges used (see Appendix E).

The inability of the subjects to maintain the pace of exactly 50 revolutions per minute during the submaximal test, as set by the metronome, was deemed to be a result of individual differences and not an inherent source of instrumental error in the test itself.

A short time delay from the time the pulse was felt until the starting of the watch causing a palpation heart rate reading consistently slower than the E.C.G. value was corrected for by means of a regression equation, established on approximately 200 raw scores for each investigator. Since it was known which person tested each subject, variation in each tester's palpation technique was diminished by means of the equation and made to more closely approach the electrocardiograph value.

Calculation of oxygen intake. The one-minute, or fifteen-second gas sample, as available, was analyzed by means of an N.V. Godart infrared capnograph for percent carbon dioxide, by means of a Beckman E-2 oxygen analyzer for oxygen content and by means of an American Meter Company gasometer (model 802) for the volume of expired air. The barometric pressure and the room temperature were recorded and the calculations, using a Montroe Calculator were as follows:

Symbols Used:

A.T.P.D. - Atmospheric Temperature and Pressure Dry.

S.T.P.D. - Standard Temperature and Pressure Dry.

A.T.P.S. - Atmospheric Temperature and Pressure Saturated.

V_e - Volume of expired air

V_i - Volume of inspired air

F_e - Percentage of expired air

F_i - Percentage of inspired air.

1. Determination of the corrected F_eO_2

F_eO_2 corrected = F_eO_2 x 2.5 (calibration constant)

2. Determination of F_eN_2

$F_eN_2 = 100 - (F_eO_2 + F_eCO_2)$ i.e. $F_eO_2 + F_eN_2 + F_eCO_2 = 100\%$.

3. Determination of the corrected V_eS.T.P.D.

V_eA.T.P.S. = l/min.

V_eS.T.P.D. = V_eA.T.P.S. x Factor (to reduce volume of moist gas to a volume of dry gas at 0^oC and 760 min. Hg.) - found on charts.

4. Determination of V_iS.T.P.D.

V_iS.T.P.D. x F_iN_2 = V_eS.T.P.D. x F_eN_2

F_iO_2 = 20.94%

constants

F_iCO_2= 00.03%

F_iN_2 = 79.03%

$$V_iS.T.P.D. = \frac{V_eS.T.P.D. \times F_eN_2}{79.03} \quad l/min.$$

5. Determination of V_iO_2

$V_iO_2 = (V_iS.T.P.D. \times 20.94) - (V_eS.T.P.D. \times F_eO_2)$ = l/min.

Processing of Data Collected

1. Accuracy of palpation technique compared with E.C.G. determination at low and high work loads.

2. Inter-individual and intra-individual variation in steady state heart rate for a given work load and hence the predicted maximal oxygen intake. Test-retest reliability coefficient.

3. Correlation between predicted maximal oxygen intake, age, height, body weight, and pre-exercise heart rate.

4. Establishment of norms of maximal oxygen intake for boys and for girls of grades X-XII, in the Province of Alberta.

5. Age differences in several of the above parameters.

Statistical Procedures

A detailed description of the statistical techniques used is found in Appendix C.

A One-Way Analysis of Variance was employed to determine if the differences between more than two means were significant. If a significant F was found the Duncan's New Multiple Range Test modified by Kramer (62) for unequal n's was used to find out which means were significantly different.

When the significance of the difference between only two means was required, a t-test was used.

Percentile norms of predicted maximal oxygen intake (Appendix A) were established for Alberta males and females, ages 15 to 19 years. The percentiles were determined by arranging the scores in order from lowest to highest, counting, and recording the values which fell at the five, ten, fifteen, etc., per cent points.

CHAPTER IV

RESULTS AND DISCUSSION

Laboratory study. Hyde (55), tested twenty-nine males and twenty-seven females of secondary school age on both the Astrand Actual Maximal Oxygen Intake Test and on the Astrand Predicted Test. He found that the Astrand-Ryhming Nomogram under-predicted the measured maximal oxygen intake expressed in liters per minute for males by approximately ten per cent. The difference was significant. The female predicted maximal oxygen intakes in liters per minute were about five per cent lower than the directly measured values but this difference was not significant. No significant differences between the variances of the predicted and actual test were found for males or for females.

Green (49), investigated several of the basic accumptions underlying the construction of the Astrand-Ryhming Nomogram. He found that the correlations between heart rate and work load, oxygen consumption and work load, and heart rate and oxygen consumption were, 0.94, 0.97 and 0.95 respectively for ten male subjects. For fourteen female subjects the correlation between oxygen consumption and work load was 0.91.

When the male values for heart rate were plotted against work load only a significant linear trend was found. The curve fitted to oxygen consumption and work load showed a statistically significant linear and quadratic trend for both males and females.

Reliability of the Astrand Predicted Maximal Oxygen Intake Test. In the present study, using the same data treated by Hyde (55) and Green (49), a comparison between inter-individual variance and intra-individual variance in steady state heart rate was made for the purpose of establishing whether or not the Astrand-Ryhming Predicted Maximal Oxygen Intake Test was able to detect differences between individuals in heart rate response to a work load set on a bicycle ergometer. It is conceivable that variable error in measurement attributable to variable instrumental inaccuracy, etc., combined with true day-by-day fluctuations within a subject in physiological parameters (in this study the heart rate response to submaximal work efforts), is so great that these sources of variance make it impossible to ascertain whether true differences between individuals exist.

Henry (51), has pointed out that the reliability coefficient is merely the measure of the ratio of inter-individual differences, or true score variance, to the total variance in test scores.

Table IV:1 shows the means, standard deviations and variances of various parameters dealt with in the laboratory part of the study.

TABLE IV:1

MEANS, STANDARD DEVIATIONS AND VARIANCES OF MALE DATA USED IN THE RELIABILITY ANALYSIS

	Test 1			Test 2		
n = 23	$\bar{X}$	s^2	s	$\bar{X}$	s^2	s
Age (months)	203					
Weight (kgm)	65.33	45.97	6.78	64.95	43.74	6.61
Steady State Heart Rate (beats/min)	142.6	147.1	12.1	142.2	114.0	10.7
MVO_2 (ml/kg/min)	45.05	57.95	7.61	45.40	49.22	7.02
MVO_2 (l/min)	2.93	0.25	0.50	2.93	0.25	0.50

TABLE IV:1 (Continued)

MEANS, STANDARD DEVIATIONS AND VARIANCES OF FEMALE DATA USED IN THE RELIABILITY ANALYSIS

n = 23	Test 1 $\bar{X}$	Test 1 s^2	Test 1 s	Test 2 $\bar{X}$	Test 2 s^2	Test 2 s
Age (months)	198					
Weight (kgm)	56.58	209.3	14.47	56.37	205.6	14.34
Steady State Heart Rate (beats/min)	146.0	114	10.7	146.4	109	10.4
MVO_2 (ml/kg/min)	31.85	16.57	4.07	31.59	20.20	4.49
MVO_2 (l/min)	1.86	0.09	0.30	1.84	0.08	0.28

The intra-individual variance, the inter-individual variance and the reliability coefficients found for steady state heart rates are tabulated in Table IV:2. The values for predicted maximal oxygen intake in liters per minute and in milliliters per kilogram per minute are also included, although it is debatable that establishing a reliability coefficient on these parameters is legitimate since they are simply calculated scores dependent upon the steady state heart rate.

It is apparent in the table that inter-individual variance accounts for the majority of the total variance in steady state heart rates, (79.3 per cent for males and 71.7 per cent for females).

The reliability coefficient for males in steady state heart rate is 0.80 and for females is 0.72. Neither of these coefficients is particularly high, however, the inter-individual variance for males is about four times larger than the combined intra-individual variance and error variance and for females the ratio is approximately 2.5 to 1.

TABLE IV:2

RELIABILITY COEFFICIENTS AND AN ANALYSIS OF INTER- AND INTRA-INDIVIDUAL VARIANCE

	s_t^2	$s_{w/i}^2$	s_x^2	r_{xx}	$\frac{s_t^2}{s_x^2} \cdot 100$
MALES (n=23)					
Steady State Heart rate	103.6	27.0	130.6	0.80	79.3
MVO_2 (l/min)	0.21	0.04	0.25	0.84	84.0
MVO_2 (ml/kg/min)	44.75	8.84	53.59	0.84	84.5
FEMALES (n = 23)					
Steady State Heart rate	80.0	31.5	111.5	0.72	71.7
MVO_2 (l/min)	0.06	0.025	0.085	0.71	71.4
MVO_2 (ml/kg/min)	9.75	8.64	18.39	0.53	53.0

n = number of paired observations

s_t^2 = inter-individual variance (true score variance)

$s_{w/i}^2$ = intra-individual variance divided by error variance

s_x^2 = total variance

$r_{xx} = \frac{s_t^2}{s_a s_b}$ = reliability coefficient

$\frac{s_t^2}{s_x^2} \cdot 100$ = per cent of total variance accounted for by true score variance

s_a = standard deviation of Test 1 scores

s_b = standard deviation of Test 2 scores.

When these steady state heart rates are converted to estimations of maximal oxygen intake expressed in liters per minute by using the Astrand-Ryhming Nomogram (6), the reliability coefficients remain about the same (0.84 and 0.71 for males and females respectively). The proportion of inter-individual variance to combined intra-individual variance and error variance also remains approximately the same (5 to 1 for males and 2.5 to 1 for females).

Thus, for both males and females, the reliability coefficients for steady state heart rates and predicted maximal oxygen intake expressed in liters per minute are adequate, since individual differences can be detected by measuring these parameters.

When the male predicted maximal oxygen intake scores are expressed in milliliters per kilogram of body weight the same differentiating effectiveness as above is maintained. But the female values tend to become the same.

This massing effect is evident when the female variances are observed. When the MVO_2 values are expressed in liters per minute the variance is 0.09. This is a standard deviation of $\pm$ 300 ml. of oxygen. When body weight is taken into consideration the variance is 16.57 or a standard deviation of $\pm$ 4.07 ml/kg/min. of oxygen. This small range possibly accounts for the drop in the reliability coefficient for females when the maximal oxygen intake values are divided by body weight. Because the range is small, minor fluctuations in a subject's score can result in an alteration in the rank order of subjects. The variance in the male scores is larger than that for females and is apparently of sufficient magnitude to absorb minor fluctuations in a

subject's score from the first to the second test, thus maintaining the rank order.

The measured physiological response to work on the bicycle ergometer was shown to be reproducible to an acceptable degree when considered alone. That is, individual differences could be detected using the steady state heart rate. But when mathematical manipulations of the heart rate responses were made, and the scores were converted to milliliters of oxygen per kilogram of body weight, the ability to differentiate between individuals, at least for the females in the sample used, became difficult. Since this score conversion technique is somewhat artificial these results substantiate the thought expressed by Borg and Dahlstrom (23) that no correlation advantage is obtained by converting the steady state heart rates to maximal oxygen intake.

Reliability of Carotid Palpation as a Means of Determining Pulse Rate during Work. In the field study, because of cost, time and facilities available, it was not possible to use an electrocardiograph to measure the heart rates of the subjects. Palpation at the carotid artery was the technique used and it was felt important that the accuracy of the three testers should be determined.

During the reliability and validity testing in the laboratory, heart rates were recorded simultaneously by means of an E.C.G. and by the palpation technique. Regression equations of the E.C.G. heart rates and the palpation heart rates were established on approximately 200 scores for each investigator.

Table IV:3 lists the regression equations for each of the experimenters.

TABLE IV:3

RELIABILITY OF CAROTID ARTERY PALPATION FOR HEART RATE DETERMINATION DURING EXERCISE

Investigator	n	Regression Equation	Range (beats/min)	r_{xy}	Deviation from ECG Value
R.H.	179	y = 1.036x - 2.71	120-170	0.984	-1.5 to -3.5
H.G.	218	y = 1.067x - 4.42	120-170	0.970	-3.5 to -7.0
R.N.	257	y = 1.001x + 5.42	120-188	0.994	-5.5 to -5.5

r_{xy} - correlation of E.C.G. values with palpation values.

Using the equations each palpation heart rate was corrected to the E.C.G. value.

The relationship between electrocardiograph and palpation heart rates at both low and high pulse frequencies was determined for one of the investigators to see if the close relationship between the two, found over a medium frequency range, still held. The correlations are presented in Table IV:4.

TABLE IV:4

CORRELATIONS BETWEEN CAROTID PALPATION AND E.C.G. VALUES AT LOW AND AT HIGH PULSE FREQUENCIES

Heart Rate Range (beats/min)	n	Correlation	Mean Deviation From E.C.G. Value (beats/min)
64 - 119	54	0.995	-2.5
120 - 170	222	0.989	-5.6
120 - 188	257	0.994	-5.5
171 - 188	35	0.845	-5.6

The table shows that a constant error was made by this individual at heart rates below 170 beats per minute. Between 171 and 188 beats per minute the correlation drops from over 0.9 to 0.8. This indicates that the error in palpation at these high heart rates is becoming more variable. Sometimes the palpation heart rate is higher than the E.C.G. value and sometimes it is lower. An inability to keep up to the rate by counting and interference as a result of muscular movement by the subject working at intensities heavy enough to produce heart rates over 170 beats per minute account for the discrepencies.

On the basis of these results for trained testers, the palpation technique is adequate for field work if each investigator establishes a correction factor for his own readings from electrocardiograph readings. It is difficult to generalize, because taking heart rates by palpation is an individual skill acquired through practice, but the evidence tends to indicate that the palpation technique becomes less accurate at heart rates exceeding 170 beats per minute and should not be used in work involving heart rates this high.

Field Study. The means and standard deviations of the predicted maximal oxygen intake and the pre-exercise heart rate values of a random sample of Alberta secondary school students are tabulated in Tables IV:5 and IV:6. The values are presented for each age group separately and with the data of all the subjects combined to form a single group.

Age differences. Differences in predicted maximal oxygen intake in liters per minute and in milliliters per kilogram of body weight per minute, among the age groups 15 to 19 years inclusive for males and for

TABLE IV:5

MALES--MEAN PREDICTED MAXIMAL OXYGEN INTAKE AND PRE-EXERCISE HEART RATE VALUES

Age	n	MVO_2[a] (ml/kg/min)	MVO_2 (l/min)	Pre-exercise Heart Rate (beats/min)
15	62	47.05 ± 8.62[b]	2.81 ± 0.54	82.5 ± 14.5
16	146	46.17 ± 8.90	2.94 ± 0.56	80.1 ± 18.9
17	162	45.73 ± 9.28	2.98 ± 0.62	78.7 ± 15.1
18	82	45.21 ± 8.36	3.06 ± 0.59	78.0 ± 14.5
19	36	43.15 ± 7.88	2.91 ± 0.54	74.7 ± 14.6
15-19	499[c]	45.69 ± 8.85	2.95 ± 0.59	79.2 ± 16.1

[a] MVO_2 - Predicted Maximal Oxygen Intake.

[b] Mean ± standard deviation.

[c] All subjects together. This group also contains a few, 14, 20 and 21 year old subjects, eleven in all, but all having scores well within the range of the 15 to 19 year old scores.

TABLE IV:6

FEMALES--MEAN PREDICTED MAXIMAL OXYGEN INTAKE AND PRE-EXERCISE HEART RATE VALUES

Age	n	MVO_2[a] (ml/kg/min)	MVO_2 (l/min)	Pre-exercise Heart Rate (beats/min)
15	78	36.45 ± 7.32[b]	1.97 ± 0.43	91.8 ± 16.5
16	152	36.95 ± 7.10	2.03 ± 0.38	91.3 ± 16.2
17	132	38.37 ± 7.22	2.09 ± 0.41	90.4 ± 15.6
18	39	36.58 ± 7.67	2.09 ± 0.50	93.4 ± 15.2
19	9	39.29 ± 12.68	2.15 ± 0.67	93.0 ± 21.8
15-19	417[c]	37.30 ± 7.37	2.04 ± 0.42	91.4 ± 16.1

[a] MVO_2 - Predicted Maximal Oxygen Intake

[b] Mean ± standard deviation.

[c] All subjects together. This group also contains a few 14, 20 and 21 year old subjects, seven in all, but all having scores well within the range of the 15 to 19 year old scores.

females, were analyzed statistically by means of a one-way analysis of variance according to the technique outlined by Garrett (46:279-288). The assumption that the samples were homogeneous in variance was justified since no significant differences among the five age groups were found.

To determine whether body size had an effect on the predicted maximal oxygen intakes of the various age groups body weight and height were also analyzed by means of an analysis of variance.

Table IV:7 summarizes these analyses for the males comparing the pertinent means, and indicating the F value found in the analysis of variance and the critical F for the appropriate degrees of freedom found in the table of F values in Garrett (46:454). The summary of the actual analysis of variance conducted for each parameter for each sex and all other statistical analyses employed in the present study are found in Appendix D.

TABLE IV:7

SIGNIFICANCE OF THE DIFFERENCES BETWEEN MEANS--MALES

Age	15	16	17	18	19	F	Critical F 0.05	0.01
n	62	146	162	82	36			
MVO_2 (ml/kg/min)	47.05	46.17	45.73	45.21	43.15	1.065	2.39	3.36
MVO_2 (l/min)	2.81	2.94	2.98	3.06	2.91	1.905	2.39	3.36
Weight (kgm)	60.12	64.23	65.82	68.93	68.11	9.312	2.40[a]	3.37[a]
Height (cms)	172.9	174.5	175.4	176.9	176.8	3.662	2.40[a]	3.37[a]

[a]Significant at the level indicated.

[a]F table values for 400 d.f. The remainder are F table values for 500 d.f. d.f.for variation within groups is 483 in this analysis.

No significant differences in predicted maximal oxygen intake between any of the age groups were found for males either in terms of liters per minute or milliliters per kilogram body weight per minute. The above Table shows, however, F values significant at the 0.01 level of confidence for both weight and height. To determine precisely where this difference lay the Duncan's New Multiple Range Test modified by Kramer (62) for use with unequal numbers of subjects in the groups was employed. Tables IV:8 and IV:9 illustrate this analysis for differences in body weight and height respectively.

TABLE IV:8

DUNCAN'S NEW MULTIPLE RANGE TEST--MALES--WEIGHT (kgm)

Age	15	16	17	19	18	Shortest Significant Ranges	
n	62	146	162	36	82		
Means	60.12	64.23	65.82	68.11	68.93	120 d.f.	∞ d.f.
15	60.12		sig.	sig.	sig.	sig. R_2 34.48	33.92
16	64.23		-	-	-	sig. R_3 35.98	35.42
17	65.82				-	- R_4 37.00	36.35
19	68.11					- R_5 37.05	37.00

Ages underscored by the same line are not significantly different in weight at the 0.01 level of confidence. 483 d.f.

TABLE IV:9

DUNCAN'S NEW MULTIPLE RANGE TEST--MALES--HEIGHT (cms)

Age	15	16	17	19	18	Shortest Significant Ranges	
n	62	146	162	36	82		
Means	172.9	174.5	175.4	176.8	176.9	120 d.f.	∞ d.f.
15	172.9		--	--	--	sig. R_2 26.38	25.95
16	174.5			--	--	-- R_3 27.52	27.09
17	175.4				--	-- R_4 28.31	27.81
19	176.8					-- R_5 28.81	28.38

Ages underscored by the same line are not significantly different in height at the 0.01 level of confidence. 483 d.f.

It will be noted that the only significant difference in height according to this test was between the 18 and 15 year olds in spite of the fact that the 18 year olds were only 0.1 cm. taller than the 19 year olds. This is a result of the difference in the number of subjects in the 18 and 19 year old age groups. Kramer's correction for different n's in Duncan's New Multiple Range Test is written algebraically as follows:

$$(M_2 - M_1)\sqrt{\frac{2n_1 n2}{n_1 + n2}}$$

As the numbers of subjects increase the magnitude of the correction factor increases; the critical difference between the means is increased proportionately and in the case of the 18 and 19 year old males the difference of 0.1 cms. is magnified sufficiently to make the 18 year olds significantly taller than the 15 year olds whereas the 19 year olds, because their n was smaller, were not significantly taller than the 15 year olds. A t-test was tried with the 19 year olds and with the 17 year olds and both were found to be significantly taller than the 15 year olds at the .05 level of confidence. The danger of using multiple t-tests is, however, well known and the results of the Multiple Range Test were considered by the author to be more valid.

With respect to body weight, the 16, 17, 18, and 19 year olds were all significantly heavier than the 15 year olds at the .01 level of confidence. The 18 year olds were significantly heavier than the 16 year olds as well but none of the other age groups were significantly different in weight. These differences are readily apparent in the accompanying tables.

Table IV:10 summarizes the analysis of variance comparing

TABLE IV:10

SIGNIFICANCE OF THE DIFFERENCES BETWEEN MEANS--FEMALES

Age	15	16	17	18	19	F	Critical F 0.05	0.01
n	78	152	132	39	9			
MVO^2 (ml/kg/min)	36.45	36.95	38.37	36.58	39.29	1.29	2.39	3.36
MVO^2 (l/min)	1.97	2.03	2.09	2.09	2.15	1.33	2.39	3.36
Weight(kgm)	54.28	55.34	55.04	57.51	56.06	1.26	2.39	3.36
Height(cms)	162.3	163.3	162.6	163.5	161.2	0.73	2.39	3.36

The critical F's are for 500 d.f. within groups and 4 d.f. between groups. d.f. within groups is 405 in this analysis.

differences in the pertinent means of the female scores. No significant differences were found among any of the age groups in any parameter examined for the females.

Discussion. It is not possible to discuss age trends since the study is cross-sectional in nature and therefore only age differences may be considered. However, for comparative purposes, in some instances, it will be convenient to graph the information.

Males. Figure IV:1 portrays the results of the present study, Morse, Schultz and Cassels (76) and Astrand (5) in milliliters of oxygen consumed per minute per kilogram of body weight over the age ranges studied by the respective investigators for males. Although the present study was conducted on a bicycle ergometer and the other two studies used a treadmill, the direction of the age differences is still of value.

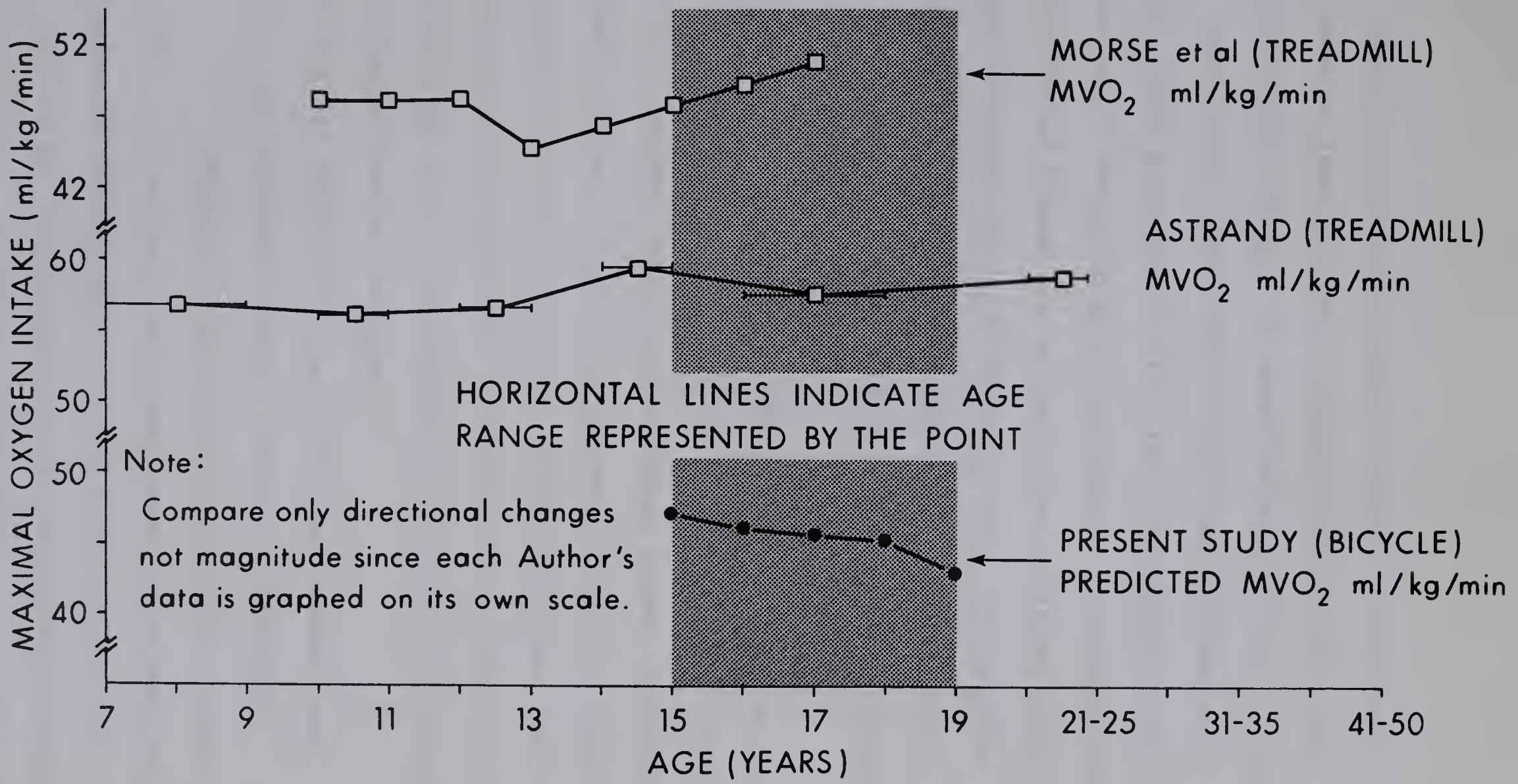
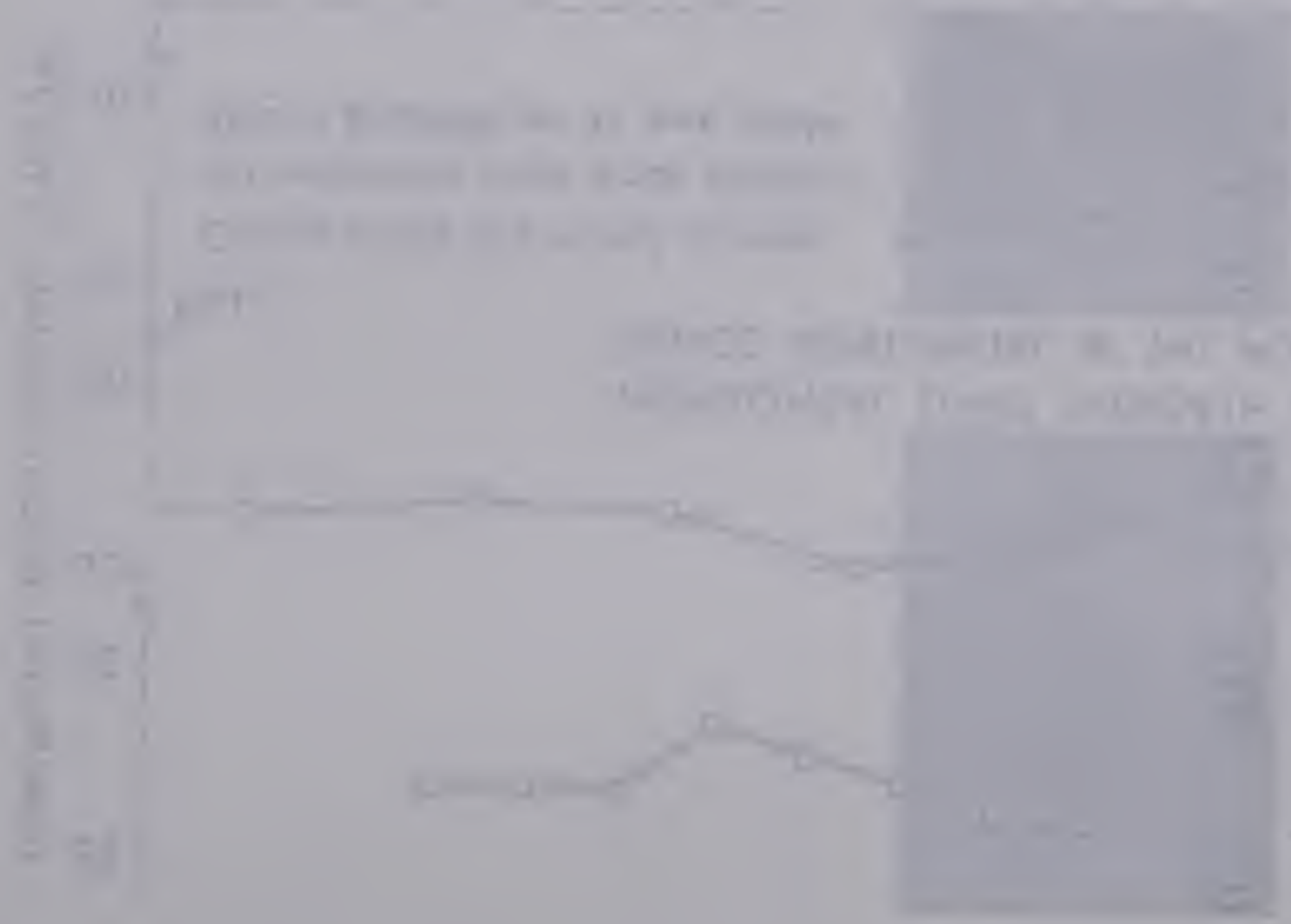


FIG IV-1 MALE AGE DIFFERENCES IN AEROBIC CAPACITY FOUND BY THREE DIFFERENT INVESTIGATIONS



It is apparent on the graph that the results of the present study are similar to those obtained by Astrand (5) but differ from those observed by Morse, et al. (76) among the ages of 15 to 17 years inclusive. Statistically, there were no significant differences in maximal oxygen intake expressed in milliliters per kilogram of body weight between any of the age groups investigated in the present study. The largest difference between any two age groups in Astrand's work was slightly smaller than the largest difference in this study and the number of subjects used by Astrand was considerably smaller, thus, it is unlikely that any of his age differences were statistically significant either.

Morse et al. showed that the 13 year olds were significantly lower (0.05 level of significance) than the 10 or 11 year olds and that the 17 year olds, the group exhibiting the highest oxygen consumption, were significantly higher than the 13 or 14 year olds but not significantly higher than the 10 or 11 year olds. Since the 15 year olds had values slightly higher than the 10 or 11 year olds the rise in maximal oxygen intake from age 15 to 17 was probably not significant although that specific analysis was not recorded.

Figure IV:2 illustrates these age differences somewhat more clearly and in a more comparable manner. The data is presented independently of units employed by the various authors and in terms of per cent of range of scores, with the highest score in the range being assigned the value 100 per cent and the lowest score zero per cent. The figure shows that the age groups commanding the lowest maximal oxygen intakes per kilogram of body weight in the present study were the 19 year

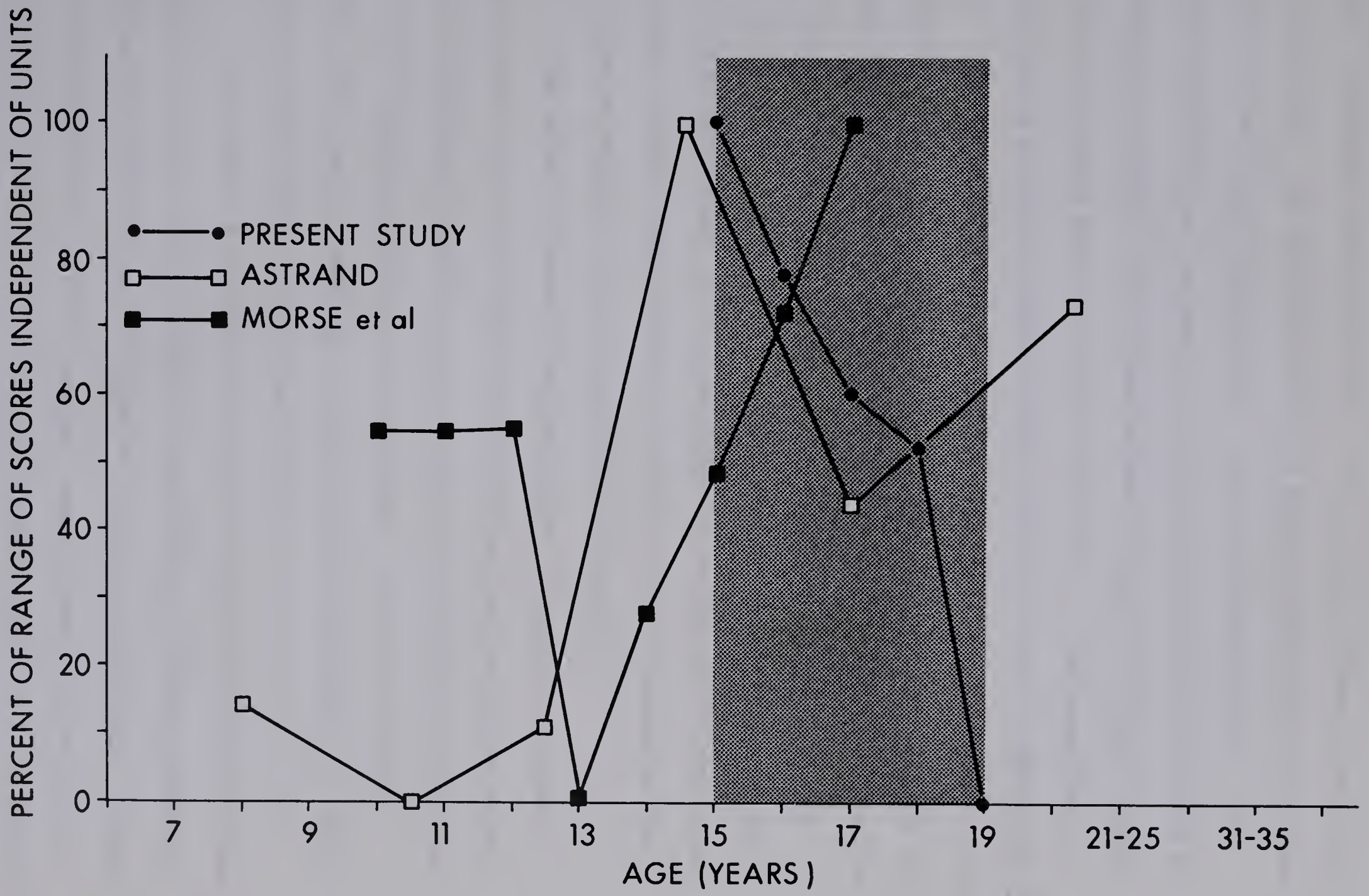


FIG IV-2 MALE AGE DIFFERENCES IN AEROBIC CAPACITY IN TERMS OF PERCENT OF RANGE OF SCORES INDEPENDENT OF UNITS (high

olds, in Astrand's work, the 10-11 year olds and in Morse's material, the 13 year olds. The age groups with the highest values were the 15 year olds, the 14-15 year olds and the 17 year olds respectively. The graph also indicates the previously mentioned parallel in the rate of lowering of maximal oxygen intake between the ages of 15 and 17 years found in Astrand's work and in this study while at the same time illustrating the exact opposite trend in the age groups of Morse, et al.

The increase in oxygen consumption in boys 13 to 17 years in the study by Morse, et al. was attributed simply to growth effects and in a large measure to effects of training in boys who are physically active. The decrease in oxygen consumption at age 13 below that of younger children was attributed to a metabolic change. Morse suggested that the oxygen requirement for a given output of energy by the muscles may be lower in the 13 year old than in younger children because of the influence of hormonal factors associated with puberty.

The abrupt increase in maximal oxygen intake per kilogram of body weight at age 14-15 years found by Astrand was associated with a rise in hemoglobin quantity per kilogram of body weight (8.0 grams per kg. to 10.0 grams per kg.) found at that age. The rise in maximal oxygen intake was followed by a slight decline at the age of 17 years similar to that found in the present study.

Any attempt to associate the age differences found in the present study with factors such as changes in hemoglobin or hormone production would be speculative since this type of data was not collected. Rather, the non-significant decline in maximal oxygen intake from the age of 15 years to 19 years in males can be attributed simply to an increase in

body weight over this age range which was significant between the 15 year olds and each of the other age groups and between the 16 and 18 year olds. This view is supported by the fact that the 15 year olds, who were the lightest, also had the lowest maximal oxygen intakes when expressed in liters per minute and the values rose slightly to age 18, then fell again at age 19 years. However, when expressed per kilogram of body weight the 15 year age group's maximal oxygen intake became the highest. None of the differences were significant. In addition, the only significant height difference was between the 15 and 18 year olds, indicating that growth had become more or less stable over the 16 to 19 year old range. This is to be expected, since the pubertal growth spurt is probably complete in the majority of males by the age of 16 years.

Figures IV:3 and IV:4 are presented to compare the results of the present study with the work of investigators who have used techniques other than prediction of maximal oxygen intake to determine an individual's ability to perform prolonged heavy work. Since each investigator employs different units to express his results the direction of change is most useful to note, although some indication of the rate of change between various ages is given by Figure IV:4. The per cent of range of scores is somewhat affected by the magnitude of the range involved, and this must be kept in mind when viewing the graph. The scores of the very young children dealt with by two of the authors reduces the lower limit of the range of scores, spreading the range considerably.

Bengtsson's (19) material shows a rise in score as the subjects

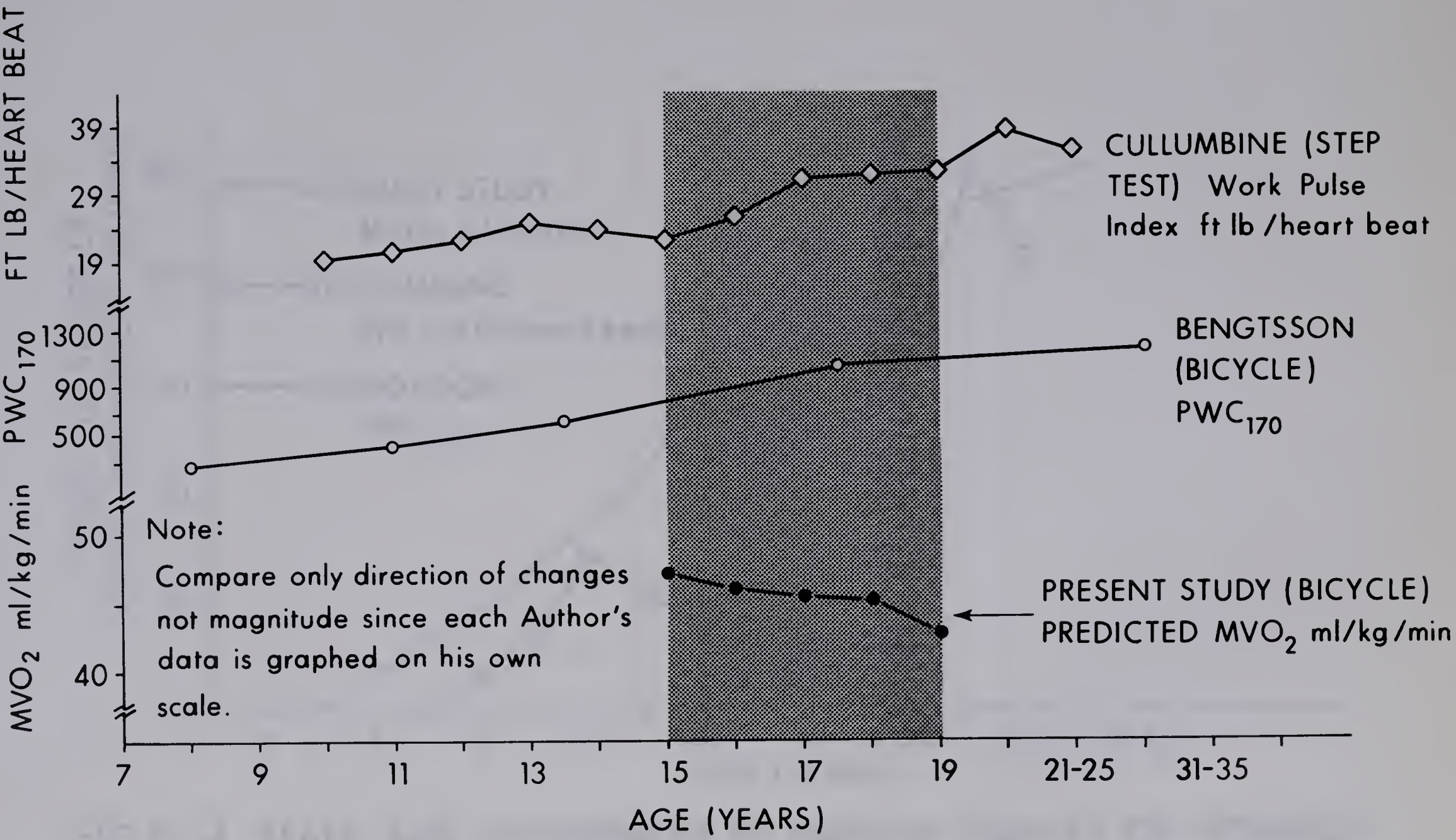
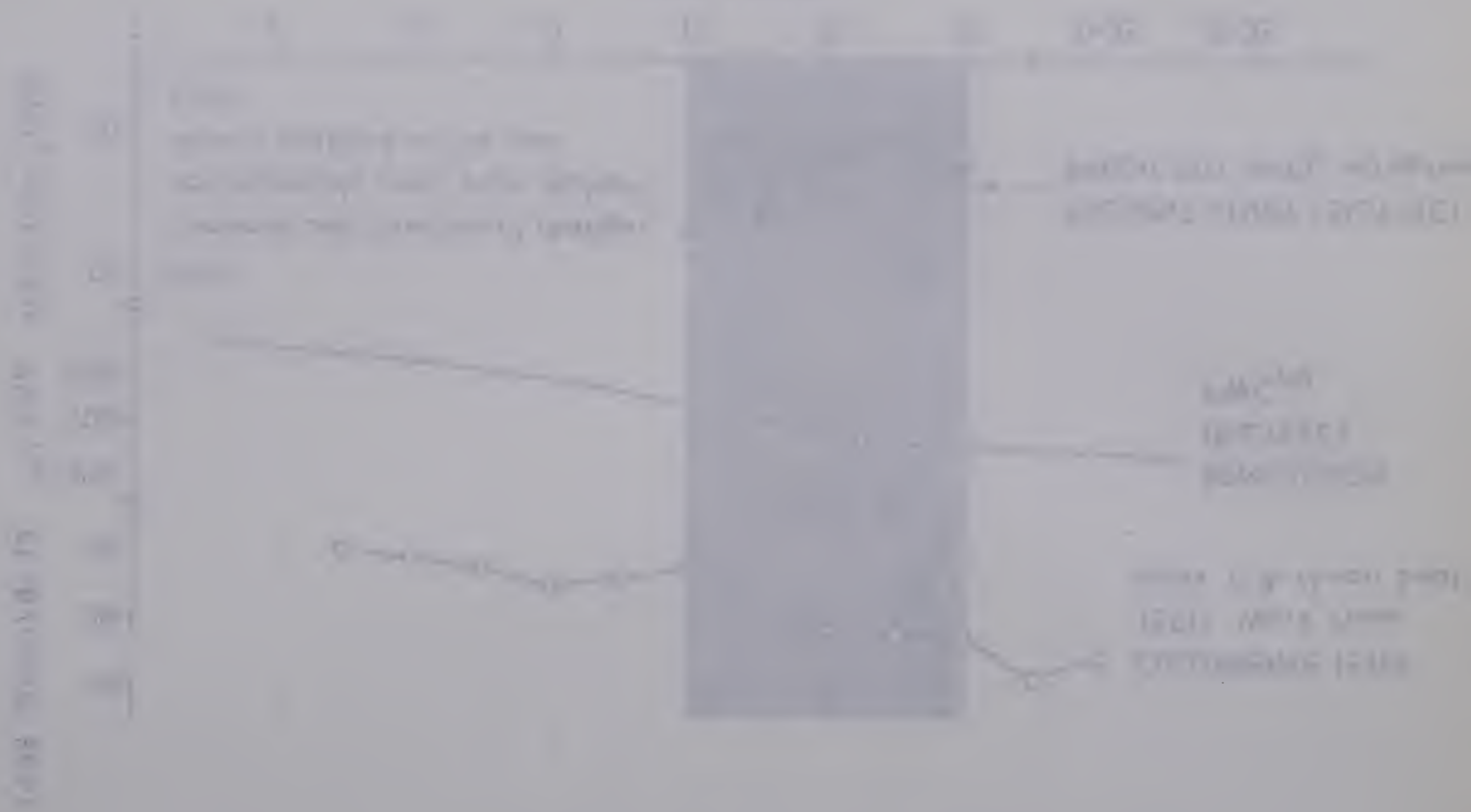


FIG IV-3 MALE AGE DIFFERENCES IN VARIOUS INDICES OF "FITNESS" FOUND BY THREE DIFFERENT INVESTIGATORS



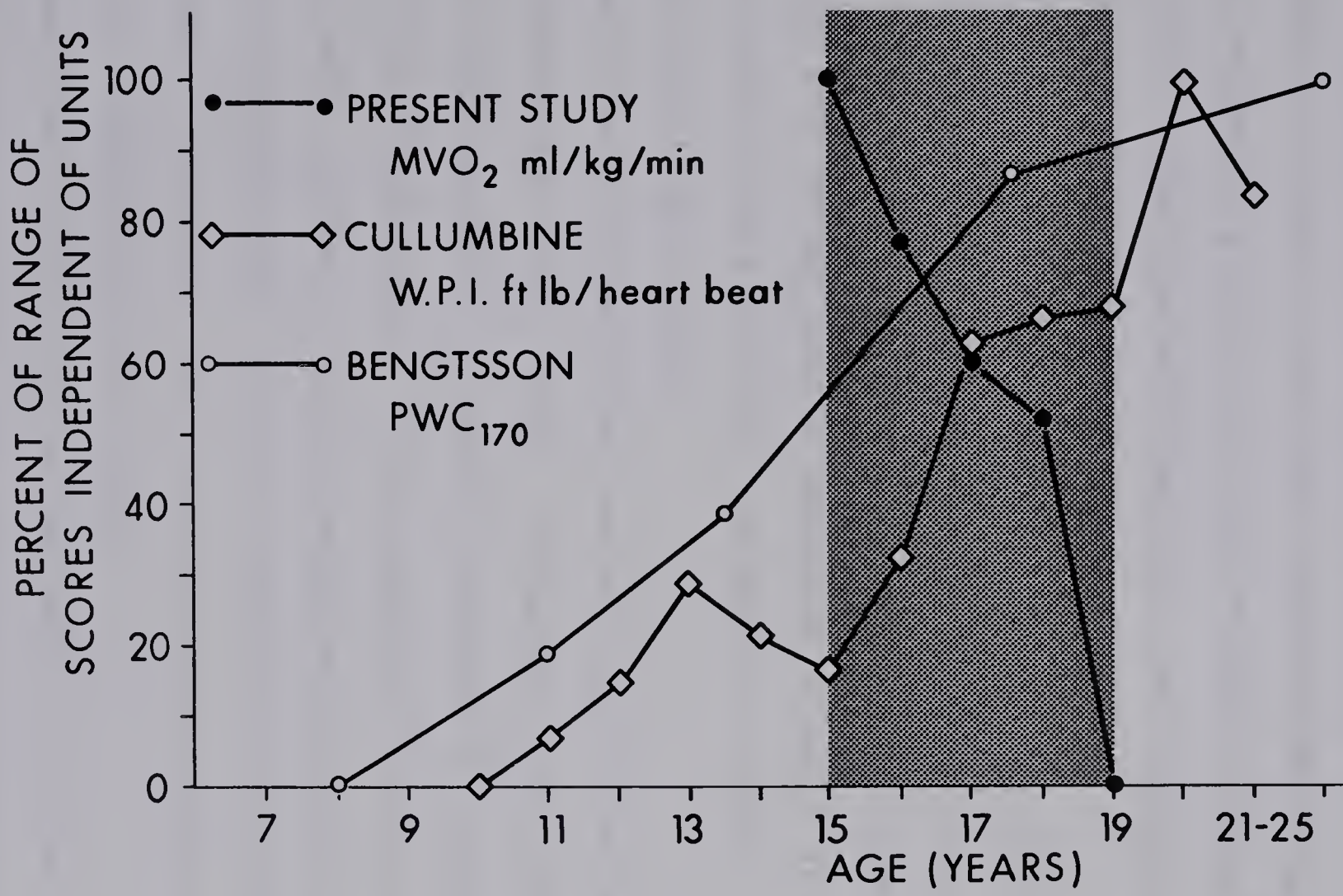


FIG IV-4 MALE AGE DIFFERENCES IN VARIOUS INDICES OF "FITNESS" IN TERMS OF PERCENT OF RANGE OF SCORES INDEPENDENT OF UNITS (high score 100%, lowest score 0%)

get older, then a deceleration in the rate of increase from age 17 to 30 years but, nevertheless, a continued increase in work capacity.

Cullumbine, et al. (29) reported a similar overall rise in "work pulse index" but with several notable interruptions. A decline in the index from the ages of 13 to 15 years supported the previously described pubertal retardation in maximal oxygen intake reported by Morse, et al. (76). This was followed by a rapid rise to age 17 years, a plateau to age 19 years similar to that observed by Bengtsson, then a sharp rise to a maximum level at age 20 years.

The data in the present study, however, is in conflict with the above-mentioned investigators, as is apparent both in Figure IV:3 and in Figure IV:4. Over the age range studied, a steady fall in work capacity was noted with the only trace of similarity, if any at all, being a slight decline in the rate of fall from age 17 to 18 years before a further drop at age 19 years.

The prime distractors, however, may revolve around the influence of body size represented by weight, height, and combined, body surface area. Since the latter parameter is generally calculated as a mathematical function of weight and height, for the purposes of this study, it is felt that any error incurred in measuring weight and height will only be magnified by transforming their values to surface area and no advantage would be gained in doing so. Height and weight relationships will then be dealt with independently of each other.

It has been shown (24) that fat-free body weight and active tissue are highly related to maximal oxygen intake ($r = 0.85$ and 0.91 respectively) and also that the nature of the task employed to elicit a

maximal oxygen intake value and the mass of muscle involved is important as well (73,88). These facts have made it useful to express maximal oxygen intake per unit of body weight since active body tissue is represented, to a greater or lesser extent, depending on the individual, by this parameter. High relationships reported between maximal oxygen intake and body weight itself (5) also support the propriety of the term.

Bengtsson (19) reported correlations between PWC_{170} and body weight for children ages 7 to 14 years of 0.89 and for young adults ages 15 to 20 years of 0.91. High correlations reported by others (1,30) using the Sjostrand Test (85) indicate that the effect of body weight should be accounted for when observing age differences using PWC_{170} as the index. Bengtsson did not do this and while it is possible that an overall upward direction in work capacity would be maintained over a wide age range, it is conceivable that over the range 15 to 19 years used in the present study, when work capacity has become somewhat more stable, Bengtsson would also have found fluctuations in the direction of his age differences in his parameter merely as a result of fluctuation in body weight. In fact, there is more justification for expressing Bengtsson's data with respect to body weight than there is for expressing the maximal oxygen intakes in the present study with respect to this parameter if the correlations between these factors are considered as seen in Table IV:11.

For Bengtsson's males ages 15 to 20 years, 83 per cent of the variance in work capacity is accounted for by variance in body weight while in the present study variance in body weight accounts for only 16 per cent of the variance in maximal oxygen intake. It is interesting in

TABLE IV:11

CORRELATIONS BETWEEN BODY WEIGHT AND "WORK CAPACITY" FOUND BY TWO DIFFERENT INVESTIGATORS USING TWO DIFFERENT INDICES--MALES

PRESENT STUDY MVO_2 l/min vs wt.				BENGTSSON PWC_{170} vs wt.			
Age	n	r	Level of Significance	Age	n	r	Level of Significance
15	62	0.49	0.01	Children 7-14	41	0.89	0.001
16	146	0.27	0.01				
17	162	0.38	0.01	Males 15-20	5	0.91	0.05
18	82	0.47	0.01				
19	36	0.39	0.05	Males 21-40	10	0.02	NS
15-19	499	0.40	0.01				

Bengtsson's material to note that body weight has no influence on the work capacity of male adults.

The divergence in the present study from the "Work Pulse Index" of Cullumbine, et al. (29) is possibly because of an over-compensation for the influence of body weight on the scores. The index was based on the number of foot pounds of work the subject did divided by his recovery pulse rate or in other words, foot pounds per pulse beat in recovery. The amount of work done was a direct function of weight and since the recovery pulse did not vary much between the ages of 15 to 19 years the major contributor to increase in the index was possibly the increase in body weight over these years rather than a true change in cardio-pulmonary function.

Females. Figures IV:5 and IV:6 illustrate the age differences found in the present study, in Bengtsson's (19) work and in the work of Astrand (5), for females.

The female age differences in the present study, when expressed in milliliters per kilogram of body weight, show a rising trend from age 15 to 17 years, a drop at age 18 and a peak at age 19 instead of the decline found in the male data. This material is consistent with that of Bengtsson and Astrand which showed an overall slight increase from age 15 to 19 years inclusive. The change, however, is not significant in the present study and was probably not significant in the studies of the other two investigators mentioned considering the magnitude of their mean differences and the number of subjects they used.

The non-significant increase in the maximal oxygen intake, that is, the relative stability, with each successive female age group, is attributed to the relative stability in growth with the surpassing of the major pubertal changes which occur in females, in most cases, prior to the age of 15 years. That physical maturity, at least, has been achieved by this age for the female subjects is supported by the fact that no significant difference in height or weight was observed over the age range studied. A sudden drop in maximal oxygen intake per kilogram of body weight at the age of 18 years was noticed but this was accompanied by a sudden rise in body weight in that particular age group. When body weight was not considered the same drop in maximal oxygen intake did not occur at this age. Thus, as for the boys, the minor deviations in MVO_2 for the girls over the ages of 15 to 19 years are probably a result of minor changes in body weight and are not a

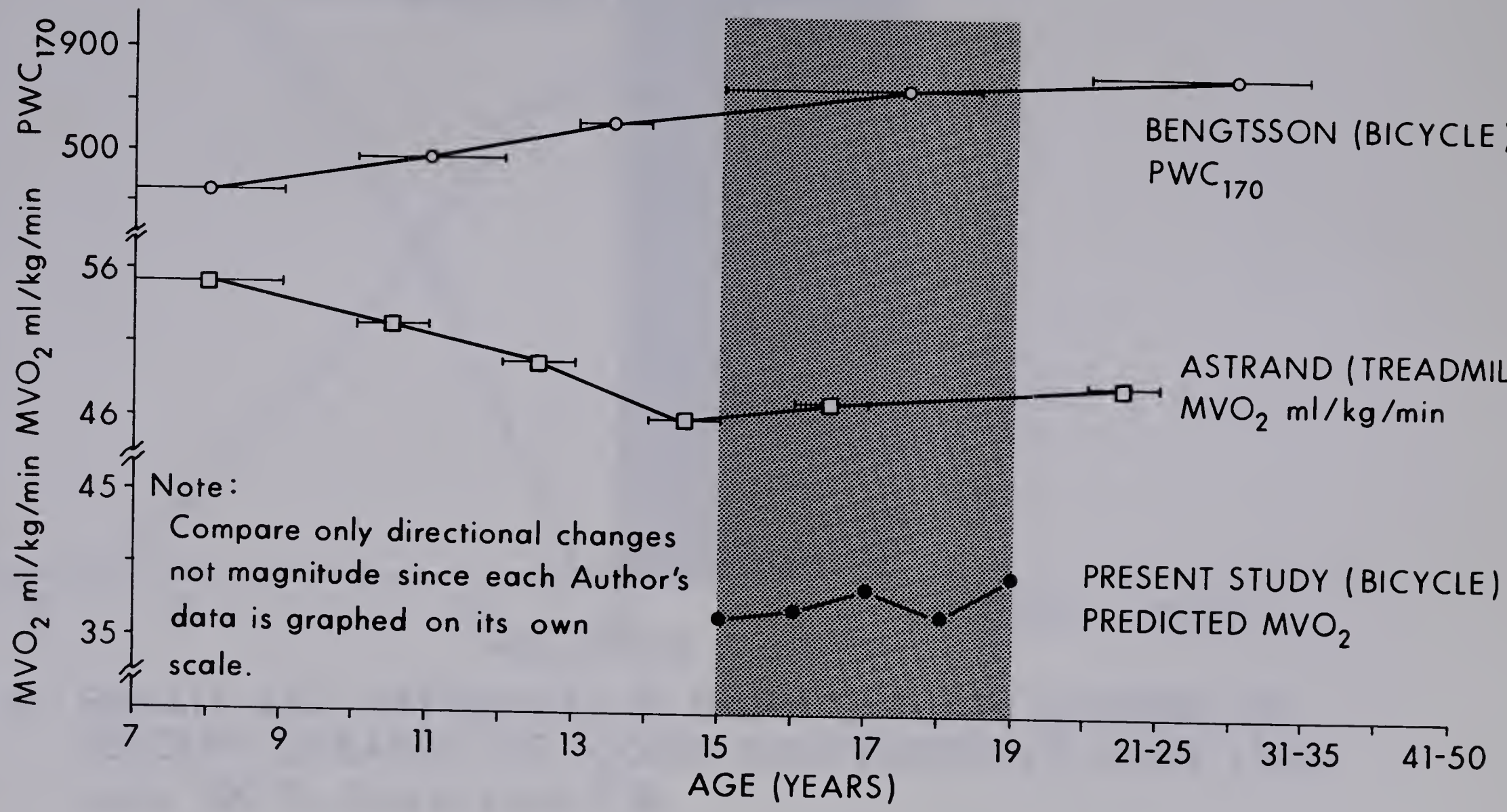
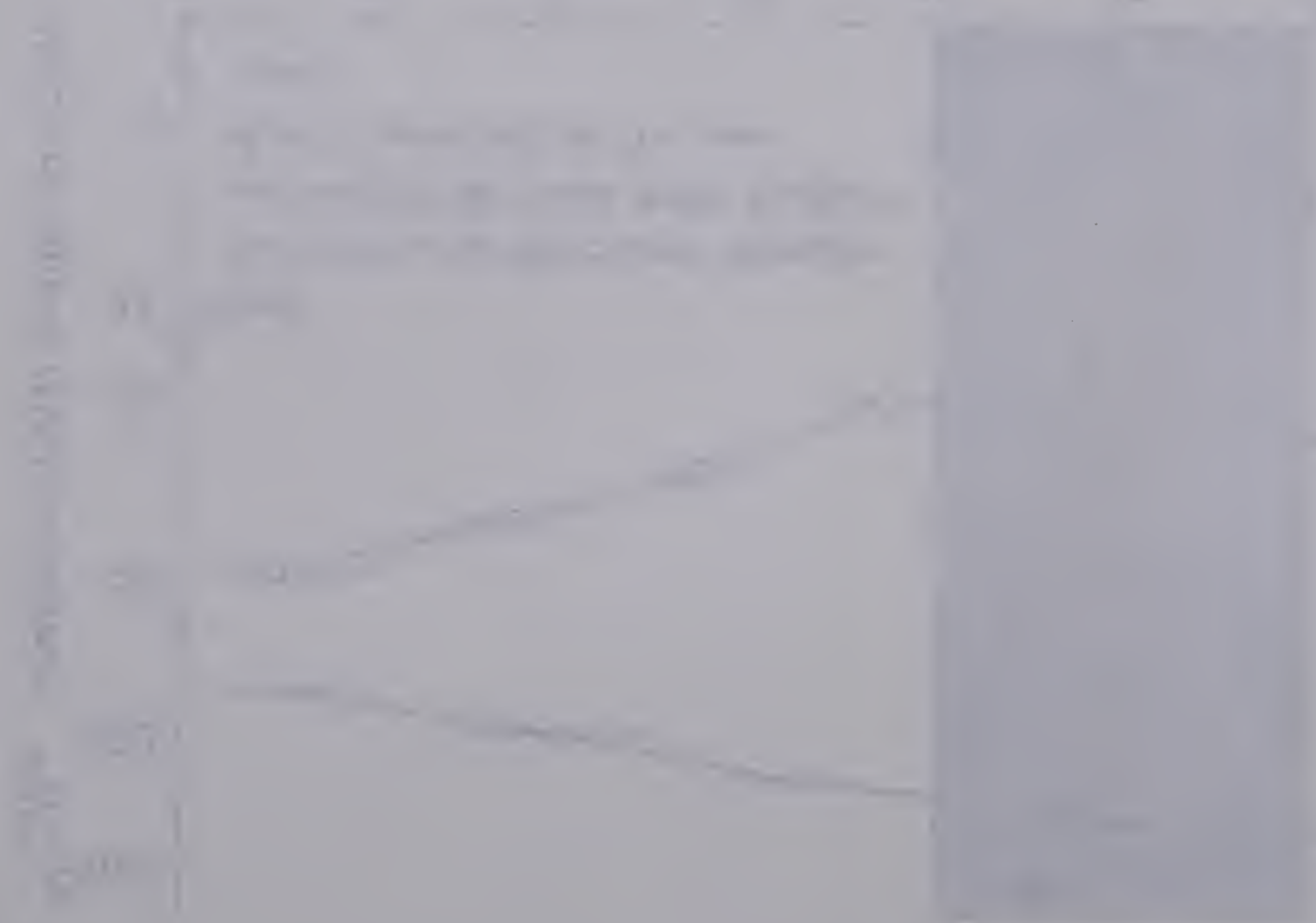


FIG IV- 5 FEMALE AGE DIFFERENCES IN "WORK CAPACITY" FOUND BY THREE DIFFERENT INVESTIGATORS



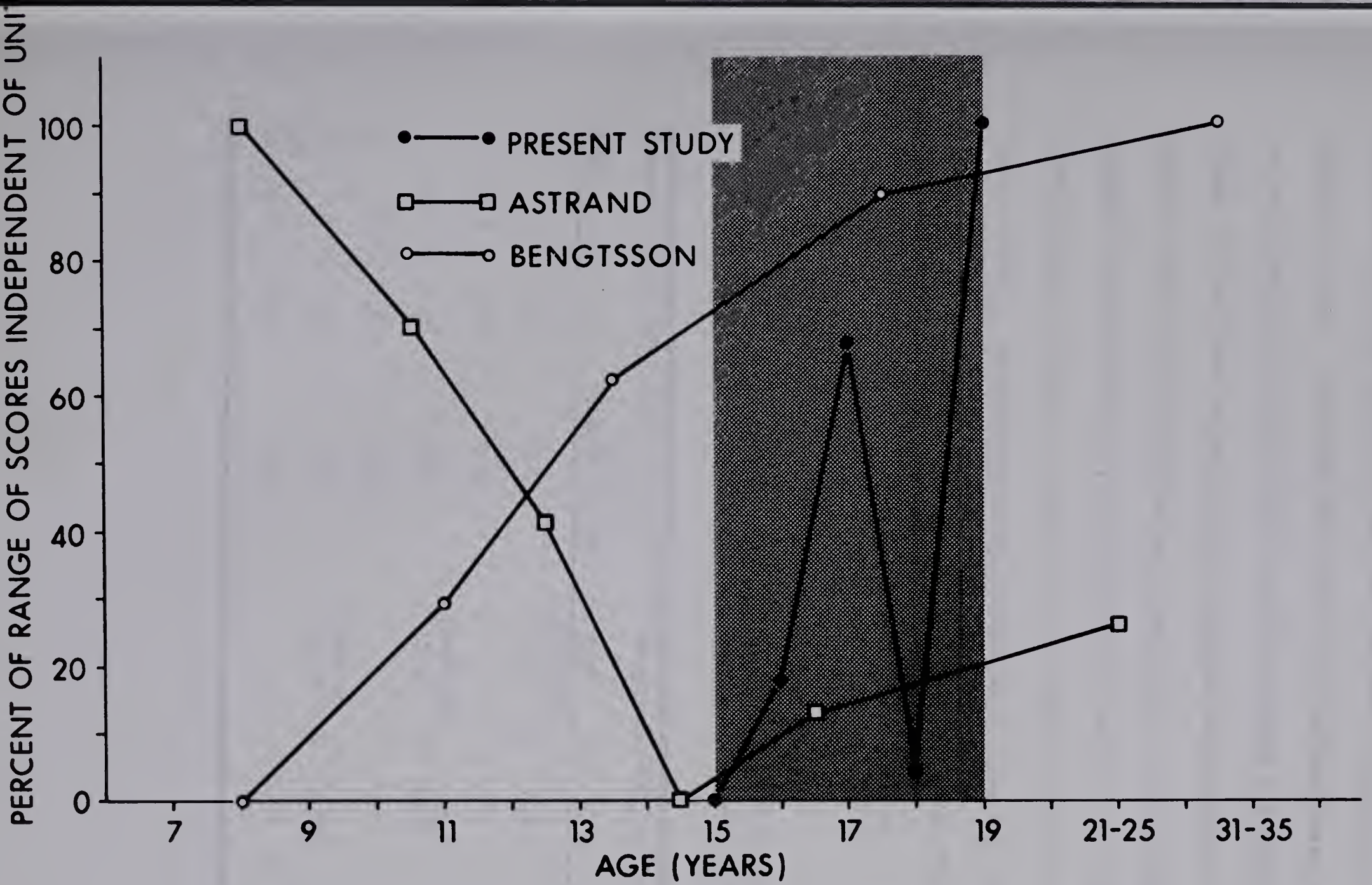
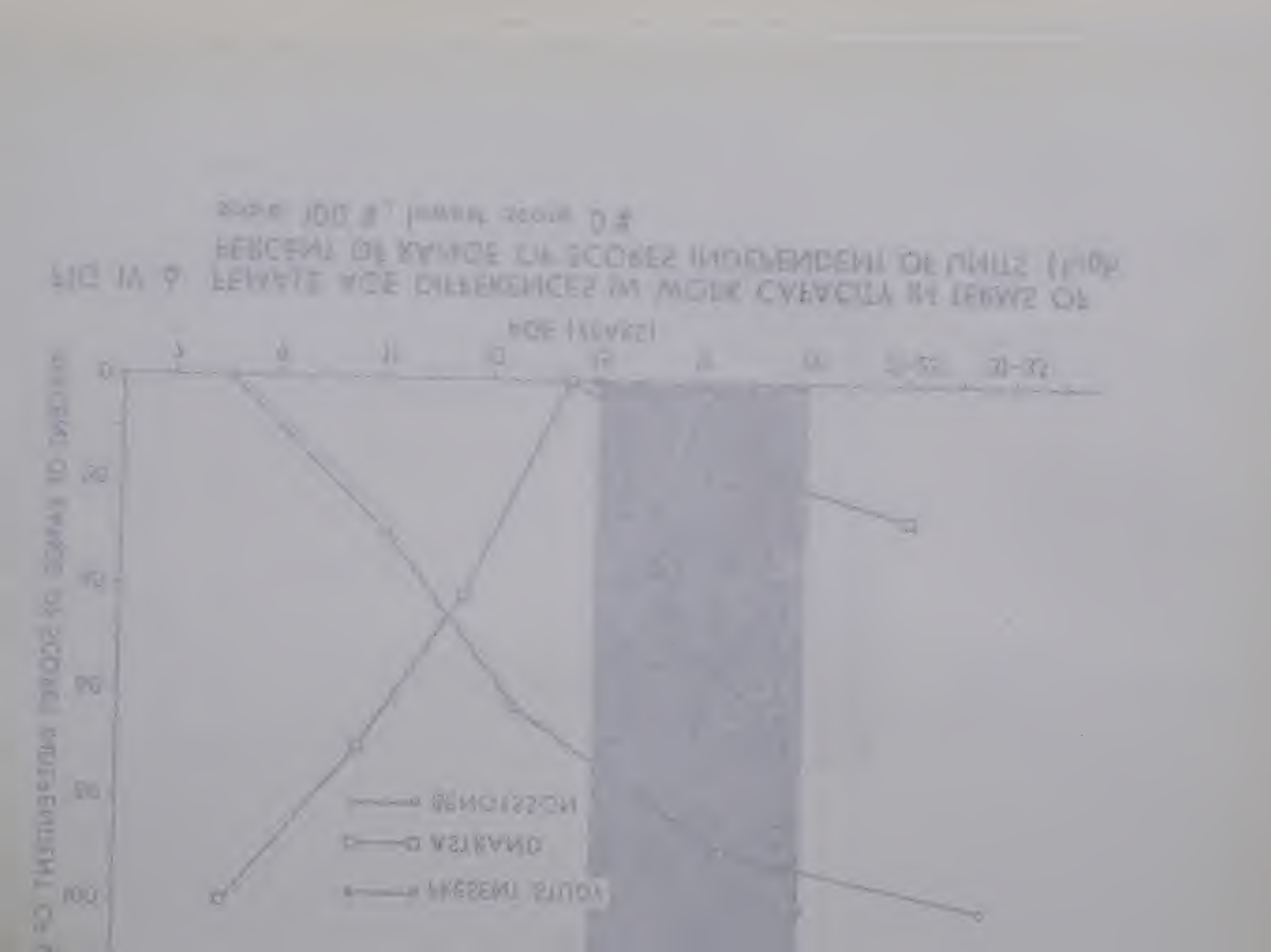


FIG IV-6 FEMALE AGE DIFFERENCES IN WORK CAPACITY IN TERMS OF PERCENT OF RANGE OF SCORES INDEPENDENT OF UNITS (high score 100 %, lowest score 0 %.



function of true cardiovascular or metabolic change.

It is conjectured that the points raised with respect to the influence of body weight on various indices for males are valid for females as well. Although Bengtsson's age differences, as presented, do not diverge much from those found by Astrand and those in the present study, if they were expressed per kilogram body weight, it is quite possible that some divergence would be found. These changes also would probably be explainable by fluctuations in weight. In this light it is interesting to observe, in Table IV:12, that for females the correlations of PWC_{170} with weight drop considerably from the comparable male values for the 15 to 20 year age group and rise considerably from the comparable male values in the 21 to 40 year age group.

TABLE IV:12

CORRELATIONS BETWEEN BODY WEIGHT AND "WORK CAPACITY" FOUND BY TWO DIFFERENT INVESTIGATORS USING TWO DIFFERENT INDICES--FEMALES

Present Study MVO_2 l/min vs wt.				Bengtsson PWC_{170} vs wt.			
Age	n	r	Level of Significance	Age	n	r	Level of Significance
				Children			
15	78	0.43	0.01	7-14	41	0.89	0.001
16	152	0.30	0.01				
				Females			
17	132	0.37	0.01	15-20	6	0.56	NS
18	39	0.45	0.01				
				Females			
19	9	0.14	NS	21-40	9	0.73	0.05
15-19	417	0.37	0.01				

In the present study the correlations remain about the same for males and for females from ages 15 to 18 years. For the 19 year old females the correlation drops to 0.14, however, only nine subjects were in that age group and they may not be entirely representative.

Variance in weight in Bengtsson's female data accounts for about 31 per cent of the variance in PWC_{170} for the girls ages 15 to 20 years. The present study shows that only about 14 per cent of the variance in maximal oxygen intake in liters per minute is explained by variance in body weight.

Height. Table IV:13 indicates that the predicted maximal oxygen intake in liters per minute is significantly related to height as well as to body weight for most age groups, both male and female. A cursory analysis of the correlation matrix will make it apparent that in all cases but one, the 19 year old males, variance in height accounts for only 16 per cent or less of the variance in maximal oxygen intake. Further scrutiny of this relationship by dealing with the first order partial correlations between weight, height and maximal oxygen intake, shown in Appendix D, reveals that in almost every instance, the relationship with height is attributable to the effect that height has on weight since the correlation of MVO_2 with height dropped to insignificant values when weight was partialled out. The one exception was with the 19 year old males. Here the correlation of maximal oxygen intake in liters per minute with height was 0.53 and with weight was 0.39. When weight was partialled out of the former correlation and height out of the latter the correlations with height remained relatively high

TABLE IV:13

SIMPLE CORRELATIONS BETWEEN VARIOUS PARAMETERS PERTINENT TO THE PRESENT STUDY

Age	n	Prex.P.R. vs MVO_2 ml/kg	Prex.P.R. vs MVO_2 l/min	Wt. vs Ht.	Prex.P.R. vs Wt.	Prex.P.R. vs Ht.	MVO_2 ml/kg vs Wt.	MVO_2 l/min vs Wt.	MVO_2 ml/kg vs.Ht.	MVO_2 l/min vs Ht.
MALES										
15	62	-0.37[a]	-0.45[a]	0.62[a]	-0.15	-0.12	-0.28[b]	0.49[a]	-0.08	0.40[a]
16	146	-0.48[a]	-0.51[a]	0.46[a]	-0.05	-0.14	-0.39[a]	0.27[a]	-0.18[b]	0.17[b]
17	162	-0.46[a]	-0.40[a]	0.48[a]	0.05	0.05	-0.31[a]	0.38[a]	-0.05	0.30[a]
18	82	-0.35[a]	-0.33[a]	0.50[a]	0.02	0.02	-0.32[a]	0.47[a]	-0.20	0.24[b]
19	36	-0.53[a]	-0.52[a]	0.53[a]	0.03	-0.16	-0.41[b]	0.39[a]	0.08	0.53[a]
14-21	499	-0.42	-0.44[a]	0.53	-0.04	-0.07	-0.34[a]	0.40[a]	-0.12[b]	0.30[a]
FEMALES										
15	78	-0.46[a]	-0.39[a]	0.40[a]	-0.15	0.01	-0.18	0.43[a]	-0.07	0.18
16	152	-0.45[a]	-0.48[a]	0.46[a]	-0.05	0.18[b]	-0.35[a]	0.30[a]	-0.21[b]	0.10
17	132	-0.37[a]	-0.38[a]	0.47[a]	0.05	-0.12	-0.31[a]	0.37[a]	-0.08	0.28[a]
18	39	-0.47[a]	-0.46[a]	0.49[a]	0.02	-0.23	-0.15	0.45[a]	0.03	0.33[b]
19	9	-0.59	-0.81[a]	0.60	0.03	-0.01	0.43	0.14	-0.26	0.16
14-21	417	-0.45[a]	-0.44[a]	0.47	-0.01	0.01	-0.28[a]	0.37[a]	-0.11[b]	0.21[a]

Prex.P.R. - Pre-exercise Pulse Rate.

[a]Correlation significant at the 0.01 level of confidence.

[b]Correlation significant at the 0.05 level of confidence.

(r = 0.42) but with weight, dropped to 0.15. The reason for the apparent anomaly for this particular age group cannot be explained by this author. No literature dealing with correlations of maximal oxygen intake with height were reviewed although the investigarors evaluating work capacity by means of the Sjostrand test (1,19,30) reported correlations with height and with surface area from 0.66 to 0.904. Detailed analysis of their correlations were not offered in the published papers, although it is speculated, based on the results of the present study, that the very high relationships of their indices with height and surface area might also be predominantly a result of the relationship they bear with body weight.

Predicted Maximal Oxygen Intake and Pre-Exercise Heart Rate. Table IV:13 indicates that high pre-exercise heart rates had an adverse effect on the magnitude of the predicted maximal oxygen intake. In each group classification the relationship between pre-exercise heart rate and maximal oxygen intake was negative and significant for both males and females. The variance in maximal oxygen intake accounted for by variance in the pre-exercise pulse ranged from 12 per cent to 28 per cent for males and from 14 per cent to 29 per cent for females. No age pattern was evident since only 1.4 per cent of the variance in pre-exercise pulse rate was attributable to variance in age for males and the relationship was even lower for females.

These findings do not support Bengtsson's (19) or Astrand's (10) belief that the working pulse is, to a high degree, resistant to changes in the mental state of the subject. Rather, the present findings are

more similar to those of Taylor, et al. (89) and Rowell, et al. (81). The former stated that initial contact with a work task can displace the pulse rate-work rate relationship to the left without causing a change in the maximal pulse rate. The effect here is to under-predict the maximal oxygen intake. Because of the nature of the field testing it was impossible to orient the subjects to the equipment or to the procedure aside from a brief explanation of the principles behind the test and the purpose of it. This was not sufficient to completely allay their anxieties and it is felt that this emotional factor is primarily responsible for the high pre-exercise heart rates observed in some cases. The mean value for males grouped together was 79.2 beats per minute with a standard deviation of 16.1 beats per minute. The females were somewhat higher with a mean value of 91.4 beats per minute and a standard deviation of 16.1 beats per minute (Tables IV:5 and IV:6). On the whole, then, the pre-exercise pulse rate was not exceptionally high, although the inverse relationship with predicted maximal oxygen intake was still present.

Predicted Maximal Oxygen Intake with Respect to "Activity Status" and Bicycle Riding. The following analyses were carried out as a by-product of the main investigation. Since this portion of the study contains information obtained by interrogating the subjects, more for interest than in an attempt to relate rigidly controlled classifications with respect to predicted maximal oxygen intake, the data will be presented without a major discussion.

Activity Status. The subjects were divided into three activity level classifications. Those who claimed that they participated in no recreational physical activity or were not taking physical education at the time of testing were classified as "not active." Subjects who were taking physical education, who played intramural sports or who participated in recreational physical activities were termed "moderately active." Those who were training for an interschool sport or who regularly trained for some other activity such as figure skating, etc., were termed "active."

Tables IV:14 and IV:15 include maximal oxygen intake, weight and height values for males and for females respectively.

The F values for the analysis of variance show that, in the case of the males, significant differences betwen the means were found in predicted maximal oxygen intake expressed per kilogram body weight and expressed in liters per minute. The Duncan's New Multiple Range Test, summarized in Table IV:16, indicates that the "highly active" group and the "moderately active" group had significantly higher maximal oxygen intakes than the "not active" group although the first two groups were not significantly different from each other.

Without accounting for body weight (Table IV:17), that is, expressing the predicted maximal oxygen intake in liters per minute, the "moderately active" group had significantly lower values than the "highly active" group. This suggests that the difference between these two groups is a result of body weight since the difference is not significant when weight is considered (Table IV:16). The lower values of the "not active" group are possibly attributable to the sedentary

TABLE IV:14

SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS MALE ACTIVITY STATUS

	Highly Active	Moderately Active	Not Active	F	Critical F 0.05	Critical F 0.01
n	122	243	134			
MVO_2 (ml/kg/min)	48.47 ± 9.29 (86.39)	46.13 ± 8.66 (75.00)	42.35 ± 7.70 (59.24)	16.96	3.02	4.66[a]
MVO_2 (l/min)	3.20 ± 0.61 (0.370)	2.96 ± 0.56 (0.316)	2.71 ± 0.51 (0.259)	22.47	3.02	4.66[a]
Weight (kgm)	66.77 ± 9.79 (95.90)	64.82 ± 9.66 (93.41)	64.62 ± 9.44 (89.20)	2.04	3.01	4.65
Height (cms)	175.8 ± 6.68 (44.58)	174.4 ± 7.32 (53.54)	176.1 ± 7.53 (56.77)	2.79	3.01	4.65

[a] Significant at level indicated in the table. F Table values for 400 d.f. within groups and 2 d.f. between groups. The remainder are F Table values for 500 d.f. within groups and 2 d.f. between groups. d.f. for variation within groups in this analysis is 498.

TABLE IV:15

SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS FEMALE ACTIVITY STATUS

	Highly Active	Moderately Active	Not Active	F	Critical F 0.05	Critical F 0.01
n	53	212	152			
MVO_2 (ml/kg/min)	40.06 ± 6.97 (48.65)	37.19 ± 7.41 (54.97)	36.48 ± 7.25 (52.56)	4.77	3.02	4.66[a]
MVO_2 (l/min)	2.24 ± 0.42 (0.168)	2.02 ± 0.41 (0.168)	2.01 ± 0.42 (0.173)	4.02	3.02	4.66[a]
Weight (kgm)	56.24 ± 7.01 (49.16)	54.85 ± 7.55 (57.07)	55.45 ± 7.65 (58.50)	0.82	3.01	4.65
Height (cms)	164.8 ± 5.80 (33.65)	162.3 ± 6.00 (36.00)	162.9 ± 6.49 (42.08)	3.52	2.03	4.66[a]

[a]Significant at the level indicated in the table. F Table values for 400 d.f. within groups and 2 d.f. between groups. The remainder are F Table values for 500 d.f. within groups and 2 d.f. between groups. d.f. for variation within groups in this analysis is 416.

TABLE IV:16

DUNCAN'S NEW MULTIPLE RANGE TEST MALE ACTIVITY STATUS
MVO_2 (ml/kg/min)

Status	Not Active	Mod. Active	Highly Active	Shortest Significant Ranges	
n	134	243	122		
Means	42.35	46.13	48.47	120 d.f.	∞ d.f.
42.35		Sig.	Sig.	R_2 31.70	31.19
46.13			--	R_3 33.08	32.57

Status subtended by same line are not significantly different in MVO_2 per kilogram body weight at the 0.01 level of confidence. d.f. in this analysis is 496.

TABLE IV:17

DUNCAN'S NEW MULTIPLE RANGE TEST MALE ACTIVITY STATUS MVO_2 (l/minute)

Status	Not Active	Mod. Active	Highly Active	Shortest Significant Ranges	
n	134	243	122		
Means	2.71	2.96	3.20	120 d.f.	∞ d.f.
2.71		Sig.	Sig.	R_2 2.07	2.04
2.96			Sig.	R_3 2.16	2.13

All means significantly different from each other at the 0.01 level of confidence. d.f. in this analysis is 496.

nature of the subjects in view of the fact that physical training has been shown to improve an individual's maximal oxygen intake.

The analysis of variance for females indicates that significant differences in means existed in predicted maximal oxygen intake per kilogram body weight, in predicted maximal oxygen intake in liters per minute and in height. The differences in the first parameter were

significant at the 0.01 level of confidence while the last two were significant at the 0.05 level. The Duncan's Test (Tables IV:18,19, 20) was only accepted at the 0.01 level of confidence, consequently this calculation revealed significant differences with respect to MVO_2 in milliliters per kilogram per minute alone. The "highly active" females were significantly higher in this index than the "not active" group but not significantly higher than the "moderately active" individuals. The latter group was not significantly higher than the "not active" group. As for the males, the reason can probably be considered to be the training effect experienced by the highly active individuals but apparently absent in the girls engaging in fewer strenuous physical activities.

Bicycle Riders and Non Riders. For the purposes of the study a "bicycle rider" was considered to be an individual who was regularly riding a bicycle at the time of the test. Whether or not he/she knew how to ride one was not recorded. The purpose was to see if a specific training effect might be observed, which could affect the results. The data for males is tabulated in Table IV:22 and for females, in Table IV:21.

The female bike riders were significantly higher in MVO_2 in both milliliters per kilogram body weight per minute ($p = 0.05$) and in liters per minute ($p = 0.01$) than the non-bike riders. Reasons for this difference are only speculative and could be any one or a combination of a specific training advantage as a result of being used to riding a bicycle, lower apprehension because of familiarity with the task or a higher skill level.

TABLE IV:18

DUNCAN'S NEW MULTIPLE RANGE TEST FEMALE ACTIVITY STATUS MVO_2 (ml/kg/min)

Status	Not Active	Mod. Active	Highly Active	Shortest Significant Ranges	
n	152	212	53		
Means	36.48	37.19	40.06	120 d.f.	∞ d.f.
36.48		--	Sig.	R_2 27.01	26.57
37.19			--	R_3 28.18	27.74

TABLE IV:19

DUNCAN'S NEW MULTIPLE RANGE TEST FEMALE ACTIVITY STATUS MVO_2 (l/minute)

Status	Not Active	Mod. Active	Highly Active	Shortest Significant Ranges	
n	152	212	53		
Means	2.01	2.02	2.24	120 d.f.	∞ d.f.
2.01		--	--	R_2 2.035	2.002
2.02			--	R_3 2.123	2.090

TABLE IV:20

DUNCAN'S NEW MULTIPLE RANGE TEST FEMALE ACTIVITY STATUS HEIGHT (cms)

Status	Mod. Active	Non Active	Highly Active	Shortest Significant Ranges	
n	212	152	53		
Means	162.3	162.9	168.8	120 d.f.	∞ d.f.
162.3		--	--	R 22.79	22.42
162.9			--	R 23.78	23.41

Status subtended by same line are not significantly different at the 0.01 level of confidence. d.f. in above analyses is 414.

TABLE IV:21

SIGNIFICANCE OF THE DIFFERENCES BETWEEN MEANS FEMALE BICYCLE RIDERS AND NON BICYCLE RIDERS

	Bike Riders	Non Bike Riders	t	Critical t .05	Critical t .01
n	80	337			
MVO_2 (ml/kg/min)	38.88 ± 7.75 (60.09)	36.92 ± 7.23 (52.31)	2.059	1.966	2.588[a]
MVO_2 (l/min)	2.16 ± 0.44 (0.192)	2.02 ± 0.41 (0.169)	2.597	1.966	2.588[a]
Weight (kgm)	55.85 ± 7.16 (51.23)	55.10 ± 3.61 (57.86)	0.832	1.965	2.586
Height (cms)	163.0 ± 6.06 (36.78)	162.8 ± 6.23 (38.83)	0.758	1.965	2.586

[a]Significant at the level indicated. t Table values for 400 d.f. The remainder are t Table values for 500 d.f. d.f. in this analysis is 415.

TABLE IV:22

SIGNIFICANCE OF THE DIFFERENCES BETWEEN MEANS MALE BICYCLE RIDERS AND NON BICYCLE RIDERS

	Bike Riders	Non Bike Riders	t	Critical t .05	Critical t .01
n	73	426			
MVO_2 (ml/kg/min)	45.80 ± 8.18 (66.84)	45.66 ± 8.96 (80.32)	0.133	1.965	2.586
MVO_2 (l/min)	2.81 ± 0.54 (0.294)	2.97 ± 0.59 (0.348)	-2.299	1.966	2.588[a]
Weight (kgm)	62.07 ± 9.52 (90.59)	65.82 ± 9.59 (91.89)	-3.107	1.966	2.588[a]
Height (cms)	173.7 ± 6.96 (48.44)	175.4 ± 7.28 (53.07)	-1.914	1.965	2.586

[a]Significant at level indicated. t Table values for 400 d.f. The remainder are t Table values for 500 d.f. In this analysis d.f. is 497.

Male values were not the same. The male non-bike riders were significantly higher in MVO_2 in liters per minute and in body weight than the bike riders. However, when body weight was considered in expressing the predicted maximal oxygen intakes the mean value fell below that of the bike riders although the difference was not now significant.

CHAPTER V

SUMMARY AND CONCLUSIONS

The present project was composed of two separate studies. One of these was a laboratory experiment designed to determine whether the Astrand Predicted Maximal Oxygen Intake Test was a suitable instrument for evaluating the "work capacity" of Alberta students of secondary school age. The other study involved the field testing of 417 secondary school females and 499 secondary school males ages 14 to 21 years for the purpose of determining age differences and establishing norms of predicted maximal oxygen intake.

Laboratory Study. Twenty-three males and twenty-three females ages 14 to 18 years were tested on two different days on the Astrand Predicted Maximal Oxygen Intake Test. Each subject was required to ride a bicycle ergometer for six minutes set at a work load estimated by the investigators to cause a steady state heart rate between 120 and 170 beats per minute. The maximal oxygen intake of the subject was predicted by means of the nomogram devised by Astrand and Ryhming (6) and the values were expressed in ml/kg of body weight/minute and in l/minute. Expired air analysis of each subject was made during one of the tests, which was prolonged to maximal work efforts, to actually measure the individual's maximal oxygen intake. The procedure followed was one outlined by Astrand (5), and modified slightly, which required the subject to ride for six minutes, rest for five minutes, then ride at

a higher resistance for six more minutes. The subject continued this series of rides and rests until he/she could go on no longer. Expired air was collected and analysed during the last minute of each ride. This actual maximal oxygen intake test was not directly pertinent to the present study.[1]

The reproducibility of the steady state heart rates on a test-retest basis was analysed by considering intra-individual variance, which also contained error variance, inter-individual variance and the reliability coefficient. This analysis was conducted as well for the maximal oxygen intake values expressed in l/min. and in ml/kg. of body weight/min. calculated from the Astrand-Ryhming nomogram.

Inter-individual variance was found to account for the majority of the variance in the steady state heart rates (79.3 per cent for males and 71.7 per cent for the females). The reliability coefficient in this parameter was 0.80 for males and 0.72 for females.

When the steady state heart rates were converted to predicted maximal oxygen intake scores expressed in liters per minute the reliability coefficients remained approximately the same as those for the steady state heart rates (0.84 for males, 0.71 for females). When body weight was taken into consideration and the predicted MVO_2 values were

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[1] Two other experimenters used portions of the data collected in these two studies.

Hyde (55) investigated the accuracy of prediction of the nomogram by comparing the actually measured maximal oxygen intake with that predicted.

Green (49) investigated some of the assumptions underlying construction of the nomogram such as the reported linear relationship between steady state heart rate and work load, between work load and O_2 consumption, and between O_2 consumption and heart rate.

expressed in ml/kg/min the male reliability coefficient remained at 0.84 but the female coefficient dropped to 0.53. The intra-individual variance was almost as large as the inter-individual variance making it very difficult to distinguish between individuals when the scores were expressed in this manner for females.

Since the method of carotid palpation was to be used to determine the working pulse rates of the subjects it was considered important that the accuracy in this technique of each of the three investigators be established. Electrocardiograph heart rates were recorded simultaneously with the palpation heart rates.

Based on approximately 200 scores for each investigator regression lines were calculated and the palpation values were adjusted to more closely approximate the E.C.G. values. This correction was possible since the extremely high correlations between E.C.G. and palpation values (0.984, 0.970, 0.994) for the three testers indicated that their errors were constant. The mean deviation of the palpated heart rates from the E.C.G. heart rates for each tester was -2.5, -5.5 and -5.5 beats per minute.

Correlations between E.C.G. and palpation values at low, medium, and high pulse frequencies were established for one of the investigators. The correlation for heart rates between 64 and 170 beats per minute remained well over 0.98 but at very high heart rates (171-188 beats per minute) the correlation dropped to 0.845 although the mean difference between palpation and E.C.G. values remained at -5.5 beats per minute.

Within the limits of the sample and experimental error several

conclusions concerning the test itself and the palpation technique appeared justified by the results of the analysis of the data.

1. Inter-individual variance was found to account for the majority of the total variance in steady state heart rates (79.3 per cent for males and 71.7 per cent for females). Intra-individual variance and error variance combined, therefore, accounted for only 20.7 and 28.3 per cent of the total variance for males and females respectively.

2. For both males and females, the reliability coefficients for steady state heart rates and for predicted maximal oxygen intake expressed in liters per minute were adequate to permit the detection of individual differences in these parameters after only one trial on the test using the Astrand-Ryhming nomogram.

3. For males, individual differences were shown in predicted maximal oxygen intake expressed per kilogram body weight but for females, dividing the MVO_2 values by their body weight apparently only massed the scores to such an extent that it was difficult to detect inter-individual differences. The measured physiological parameter, the steady state heart rate, was shown to be reproducible, but for females the calculated MVO_2 in ml/kg/min was not. No correlation advantage was gained by converting the steady state heart rates to MVO_2 and for females a decided disadvantage was met when their scores were expressed per kilogram of body weight.

4. On the basis of the high correlations found for trained investigators, between palpated and E.C.G. heart rates, the palpation technique is adequate for field work if each investigator establishes a correction factor for his own readings from electrocardiograph readings.

Field Study. The subjects were randomly selected and represented three per cent of every secondary school population in each of forty-four towns and cities used by the Dominion Bureau of Statistics in their labour force studies in the Province of Alberta. These towns and cities were deemed to be representative of the entire Alberta population by the D.B.S. on a socio-economic, geographic, industrial and population density basis.

The subjects were tested on the Astrand Predicted Maximal Oxygen Intake Test. Their heart rates were determined by carotid palpation and the steady state heart rate observed in each case was converted to maximal oxygen intake expressed in liters per minute and in milliliters per kilogram of body weight using the Astrand-Ryhming Nomogram (6).

Norms of predicted maximal oxygen intake for Alberta males and females ages 15 to 19 years were established.

No significant differences between any of the age groups in predicted maximal oxygen intake expressed per kilogram of body weight or expressed simply in liters per minute were found for males or for females.

All male age groups were heavier than the 15 year olds ($p = 0.01$) and the 18 year old males, the heaviest group, were significantly heavier than the 16 year olds. No significant difference in weight between any of the female age groups was found.

Sixteen per cent of the variance in predicted maximal oxygen intake for males and 14 per cent for females was accounted for by body weight. Height also correlated with predicted MVO_2 to about the same extent as weight but the first order partial correlations, where the

effect of weight was partialled out, showed that this relationship was spurious and attributable to the correlation of weight with height.

The predicted MVO_2 showed a correlation with age in months of only 0.10 for males and 0.11 for females. Thus only 1.0 per cent of the variance for males in MVO_2 and 1.2 per cent for females was accounted for by variance in age in months.

High pre-exercise pulse rates led to lower predicted maximal oxygen intakes as indicated by the consistently negative correlations. Variance in maximal oxygen intake accounted for by variance in pre-exercise pulse rate ranged over the five age groups from 12 to 28 per cent for males and from 14 to 29 per cent for females. No age pattern in pre-exercise pulse rate was evident since only 1.4 per cent of its variance was attributable to age for males and the relationship was even lower for females.

A very minor part of the study involved interrogating the subjects to subjectively classify them as to the amount of physical activity they regularly participated in and whether they had been regularly riding a bicycle prior to the test.

The male groups classified as "highly active" and "moderately active" had a significantly higher ($p = 0.01$) predicted MVO_2 per kilogram of body weight than the "not active" group. The "moderately active" and the "highly active" groups were not significantly different from each other.

When body weight was not considered and MVO_2 was expressed in liters per minute the same relationships as above for males were observed except that this time the "moderately active" group was

significantly lower than the "highly active" group as well. The latter difference, however, was explainable by a difference in body weight since the difference became not significant when weight was considered.

The "highly active" females had a significantly higher predicted MVO_2 per kilogram of body weight than the "not active" females ($p = 0.01$). The "highly active" group was not significantly different from the "moderately active" group nor was the latter group significantly different from the "not active" group in this parameter. No other differences were significant.

The female bicycle riders were significantly higher than the non riders in predicted MVO_2 both per kilogram of body weight ($p = 0.05$) and in liters per minute ($p = 0.01$). The male values, however, were opposite. The male non-bicycle riders were significantly higher in predicted MVO_2 in liters per minute ($p = 0.05$) than the bicycle riders. This difference was attributable to weight since they were also significantly heavier ($p = 0.01$) than the bicycle riders but when weight was accounted for the difference in MVO_2 was not significant.

Within the limits of experimental error and the sample used the following inferences appear to be justified.

1. There is no great difference in the amount of physical activity participated in by Alberta males between the ages of 15 and 19 years inclusive, or in that participated in by Alberta females between the ages of 15 and 19 years inclusive since no significant differences in predicted maximal oxygen intakes expressed per kilogram body weight or in liters per minute were observed among these age groups for males or for females.

2. Within these ages the non significant decline in MVO_2 expressed in ml/kg/min for males and the non significant rise in the same parameter for females can be explained by fluctuations in body weight and are probably not a result of changes in cardio-respiratory function.

3. Only 16 per cent of the variance in predicted maximal oxygen intake for males and 14 per cent for females was accounted for by variance in body weight. The commonly used procedure of equating subjects by dividing their maximal oxygen intake values by their body weight, therefore, over-compensates for the influence that body weight has on these values.

4. It is not meaningful to express maximal oxygen intake per unit of height or per square meter of body surface area since the relationship between MVO_2 and height has been shown to be almost entirely attributable to the relationship body weight bears with height. Surface area, in the manner in which it is usually calculated, is simply a mathematical function of height and weight.

5. High pre-exercise pulse rates have a definite tendency to reduce the magnitude of the predicted maximal oxygen intake. Factors which raise the level of the pre-exercise pulse rate also raise the level at which the pulse rate plateaus in submaximal work.

6. Since the subjects in the "highly active," the "moderately active" and the "not active" groups showed significant differences in maximal oxygen intake per kilogram of body weight in the direction expected it appears that the Astrand Predicted Maximal Oxygen Intake Test is sensitive enough to distinguish between individuals engaged in

different levels of activity at least to the extent indicated by the three classifications arbitrarily used in the present study.

Recommendations. The results of the present study and the review of literature in the area of "work capacity" have led to the following recommendations for future work in fitness evaluation.

Work Capacity. 1. The whole concept of work capacity tests involving predictions of one physiological parameter from the measurement of another should be reconsidered in depth. It is quite possible that this type of manipulation does not facilitate the detection of individual differences and in some cases the differentiating effectiveness of the test may even be reduced in the transposition of terms.

2. Since an elevated pre-exercise pulse rate appears to affect the level at which the exercise pulse rate plateaus during submaximal work investigation of the feasibility of establishing some sort of index based on the amount of pulse rate rise above the pre-exercise level should be conducted.

3. Further study relating weight with maximal oxygen intake should be undertaken with the objective of determining a more suitable technique for equating subjects than simply dividing their maximal oxygen intake values by their body weight.

Age Trends in Cardio-respiratory Fitness. A sample representative of the adult population and of the elementary and junior high school populations should be tested to provide comprehensive information on age differences in cardio-respiratory endurance. This material would help

determine whether appreciable fluctuations occur prior to adulthood and at what age adult decline begins. Work could then be begun to establish whether this decline can be postponed and if so, how much and what types of activity are sufficient to postpone it. Both longitudinal and cross-sectional, clinical and experimental research would be of great value in this area.

School Physical Education Curriculum. Since "physical fitness" is one of the objectives of school physical education, objective evaluation of changes in cardio-respiratory endurance and strength over the school year should be conducted on a large scale. If it is found that no change accrues from the curriculum time allotted to physical education, the program should be altered either to provide more strenuous activity or to concentrate on objectives other than fitness.

Coordinated Research. Although considerable evidence exists to indicate that lack of physical activity is related to the incidence of cardiovascular disease it is apparently not sufficient to encourage the majority of individuals to increase their activity level. Teenagers and young adults particularly, do not consider heart ailment to be a personal threat. Consequently, they are not willing to work, for no reward, at something which they probably see as physical drudgery. Further experimental and clinical investigation is needed to find out if there is a relationship between physical activity and resistance to mental fatigue, freedom from common communicable diseases such as colds and other ailments which cause a loss in working hours, since these are things of personal concern.

If these problems are to be solved, piece-meal research must be avoided and a nationally and internationally coordinated effort must be made to prevent unnecessary overlap and to promulgate progress in areas which are discrete yet closely related. Authorities in various parts of the country must assemble and decide what problems in physical fitness are most pressing. When an order of priority has been established a unified approach to designing experiments in an effort to answer the questions must be undertaken.

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APPENDIX A

NORMS

PERCENTILE NORMS

PREDICTED MAXIMAL OXYGEN INTAKE
(milliliters/kilogram body weight/min)

Males	Percentile	Females
75.87	100th	62.17
61.20	95th	49.71
57.78	90th	47.54
55.35	85th	44.58
53.46	80th	43.19
51.32	75th	41.55
49.49	70th	40.63
48.50	65th	39.73
47.10	60th	38.65
46.10	55th	37.65
45.03	50th	36.73
44.21	45th	35.85
43.24	40th	35.17
41.90	35th	34.19
40.41	30th	33.08
39.24	25th	32.05
37.60	20th	31.02
35.84	15th	29.80
34.52	10th	27.81
32.56	5th	25.84

Based on 499 male scores and 417 female scores.
Predominantly ages 15 to 19 years inclusive.

PERCENTILE NORMS

PREDICTED MAXIMAL OXYGEN INTAKE
(liters/minute)

Males	Percentile	Females
5.06	100th	3.43
4.02	95th	2.84
3.73	90th	2.63
3.59	85th	2.48
3.44	80th	2.39
3.28	75th	2.31
3.19	70th	2.20
3.09	65th	2.15
3.03	60th	2.10
2.95	55th	2.02
2.92	50th	1.98
2.85	45th	1.95
2.76	40th	1.93
2.66	35th	1.89
2.58	30th	1.87
2.52	25th	1.77
2.43	20th	1.68
2.33	15th	1.60
2.23	10th	1.49
2.18	5th	1.36

Based on 499 male scores and 417 female scores.
Predominantly ages 15 to 19 years inclusive.

PERCENTILE NORMS FOR ALBERTA MALES

PREDICTED MAXIMAL OXYGEN INTAKE
(milliliters/kilogram body weight/min)

Percentile	Age 15	16	17	18	19	Percentile
100th	70.47	67.49	73.90	75.87	58.04	100th
95th	61.66	61.40	61.57	57.94	55.23	95th
90th	58.84	58.78	58.75	56.86	53.70	90th
85th	56.07	56.18	54.99	55.15	52.98	85th
80th	54.28	54.47	53.86	50.16	49.25	80th
75th	54.28	52.75	51.80	49.43	48.32	75th
70th	50.20	50.40	49.83	47.98	45.97	70th
65th	49.06	49.48	48.33	47.10	45.16	65th
60th	47.23	48.50	46.71	46.10	44.67	60th
55th	46.96	47.16	45.27	45.47	44.10	55th
50th	46.57	45.73	44.26	45.13	43.33	50th
45th	45.68	44.77	43.68	44.70	42.06	45th
40th	44.87	44.08	42.69	43.35	41.12	40th
35th	43.40	42.91	40.76	41.37	39.75	35th
30th	42.48	41.32	39.78	40.41	38.32	30th
25th	41.43	39.33	38.89	39.42	35.84	25th
20th	39.91	37.85	36.64	37.63	35.49	20th
15th	37.86	36.14	35.34	36.29	35.30	15th
10th	34.75	34.34	34.35	34.11	35.17	10th
5th	33.52	31.00	33.09	33.19	29.13	5th
n =	62	146	162	82	36	

PERCENTILE NORMS FOR ALBERTA FEMALES

PREDICTED MAXIMAL OXYGEN INTAKE
(milliliters/kilogram body weight/min)

Percentile	Age 15	16	17	18	Percentile
100th	58.08	62.17	61.78	50.81	100th
95th	49.71	48.28	49.51	48.81	95th
90th	45.47	44.98	47.70	47.92	90th
85th	43.19	43.45	45.19	45.56	85th
80th	42.34	42.14	43.75	42.92	80th
75th	40.17	41.11	42.52	42.71	75th
70th	38.98	40.04	41.47	41.18	70th
65th	38.40	39.33	40.91	40.03	65th
60th	37.83	38.40	40.13	36.28	60th
55th	37.03	37.44	39.29	35.37	55th
50th	36.38	36.48	37.74	35.28	50th
45th	34.86	35.70	36.93	34.23	45th
40th	33.91	34.93	36.05	33.37	40th
35th	32.18	34.19	35.35	32.42	35th
30th	31.60	33.08	34.05	31.31	30th
25th	30.59	32.15	33.02	30.26	25th
20th	29.82	31.09	32.00	30.05	20th
15th	29.50	29.41	31.04	28.75	15th
10th	27.41	27.46	30.04	27.40	10th
5th	26.19	26.17	25.99	22.46	5th
n =	78	152	132	39	

PERCENTILE NORMS FOR ALBERTA MALES

PREDICTED MAXIMAL OXYGEN INTAKE
(liters/min)

Percentile	Age 15	16	17	18	19	Percentile
100th	3.99	4.42	5.06	4.60	4.42	100th
95th	3.69	3.94	4.19	4.26	3.61	95th
90th	3.50	3.71	3.80	3.89	3.56	90th
85th	3.30	3.56	3.69	3.69	3.52	85th
80th	3.27	3.41	3.52	3.59	3.41	80th
75th	3.21	3.29	3.30	3.47	3.30	75th
70th	3.08	3.21	3.17	3.25	3.08	70th
65th	2.95	3.08	3.11	3.07	3.06	65th
60th	2.94	3.03	3.04	3.06	3.00	60th
55th	2.92	2.94	2.95	3.01	2.97	55th
50th	2.87	2.88	2.88	2.97	2.90	50th
45th	2.83	2.80	2.83	2.95	2.83	45th
40th	2.68	2.75	2.71	2.88	2.78	40th
35th	2.55	2.66	2.64	2.83	2.53	35th
30th	2.46	2.56	2.59	2.75	2.52	30th
25th	2.41	2.52	2.56	2.62	2.43	25th
20th	2.34	2.44	2.46	2.53	2.34	20th
15th	2.23	2.35	2.34	2.39	2.23	15th
10th	2.11	2.29	2.24	2.29	2.20	10th
5th	1.86	2.19	2.18	2.22	2.18	5th
n =	62	146	162	82	36	

PERCENTILE NORMS FOR ALBERTA FEMALES

PREDICTED MAXIMAL OXYGEN INTAKE
(liters/min.)

Percentile	Age 15	16	17	18	Percentile
100th	3.17	3.11	3.05	3.43	100th
95th	2.75	2.87	2.78	2.97	95th
90th	2.41	2.51	2.64	2.75	90th
85th	2.33	2.41	2.53	2.61	85th
80th	2.28	2.47	2.40	2.51	80th
75th	2.27	2.27	2.34	2.42	75th
70th	2.12	2.17	2.28	2.23	70th
65th	2.09	2.12	2.19	2.19	65th
60th	2.00	2.04	2.17	2.04	60th
55th	1.97	2.02	2.11	2.01	55th
50th	1.93	1.98	2.04	2.00	50th
45th	1.89	1.95	1.98	1.95	45th
40th	1.88	1.93	1.95	1.93	40th
35th	1.78	1.89	1.91	1.89	35th
30th	1.74	1.88	1.87	1.88	30th
25th	1.61	1.85	1.78	1.76	25th
20th	1.55	1.76	1.77	1.63	20th
15th	1.49	1.65	1.68	1.60	15th
10th	1.43	1.53	1.56	1.47	10th
5th	1.36	1.36	1.42	1.28	5th
n =	78	152	132	39	

APPENDIX B

SAMPLE OF SECONDARY SCHOOLS TESTED

SAMPLE OF SECONDARY SCHOOLS TESTED

Town or City	School
Edmonton	Bonnie Doon
	Eastglen
	Queen Elizabeth
	Ross Sheppard
	Strathcona
	Victoria Vocational
	Victoria Composite
	Austin O'Brien
	O'Leary
	St. Mary's Boys
	St. Mary's Girls
	St. Joseph's
Calgary	St. Francis
	Holy Cross
	St. Mary's Boys
	St. Mary's Girls
	Central
	Forest Lawn
	Vicount Bennett
	Western Canada
	Henry Wise Wood
	Queen Elizabeth
	William Aberhart
	Montgomery
	Crescent Heights
	Ernest Manning
	James Fowler
Red Deer	Lindsay Thurber
	Red Deer Vocational
	St. Thomas Aquinas
Grande Prairie	Grande Prairie H.S.
	Grande Prairie Vocational
	St. Josephs
Lethbridge	Lethbridge Collegiate Institute
	Winston Churchill
	St. Francis Boys
	St. Francis Girls
Medicine Hat	Medicine Hat H.S.
	Crescent Heights
	McCoy

Town or City	School
Wetaskiwin	Wetaskiwin H.S.
Ponoka	Ponoka H.S.
Camrose	Camrose H.S. St. Patricks
Rimbey	Rimbey H.S.
Taber	W.R. Myers St. Mary's
Coleman	Coleman H.S.
Magrath	Magrath H.S.
Claresholm	Claresholm H.S.
Vauxhall	Vauxhall H.S.
Bon Accord	Bon Accord H.S.
Lac La Biche	Dr. Swift H.S.
Wainwright	Wainwright H.S. Wainwright R.C.H.S.
Edgerton	Edgerton H.S.
Legal	Legal H.S.
Hughenden	Hughenden H.S.
St. Paul	Racette H.S. Glen Avon
Vilna	Vilna H.S.
Boyle	Boyle H.S.
Thorhild	Thorhild H.S.
Eckville	Eckville H.S.
Caroline	Caroline H.S.
Hanna	Hanna H.S.
Lamont	Lamont H.S.

Town or City	School
Fort Saskatchewan	Fort Saskatchewan H.S.
Oyen	Oyen H.S.
Jasper	Jasper H.S.
Edson	Edson H.S.
Niton	Niton H.S.
Bentley	Bentley H.S.
Irvine	Irvine H.S.
Hines Creek	Hines Creek H.S.
Fairview	Fairview H.S. St. Thomas More
Banff	Banff H.S.
Hinton	Hinton H.S.
Canmore	Canmore H.S.
Mannville	Mannville H.S.
Hairy Hill	Hairy Hill H.S.
Grimshaw	Grimshaw H.S. Grimshaw Separate School

APPENDIX C

STATISTICAL TREATMENT

Computation of the Mean (46:27)

$$\bar{X} = \frac{\Sigma x}{N}$$

$\bar{X}$ = mean

Σx = the sum of the values for each observation, x

N = number of scores.

Computation of the Standard Deviation and Variance (46:53)

$$S_x^2 = \frac{\Sigma x^2}{N} - \left(\frac{\Sigma x}{N}\right)^2$$

$$S_x = \sqrt{S_x^2}$$

S_x^2 = variance of the x scores

Σx^2 = the sum of the values for each observation of x squared

N = number of scores

S_x = standard deviation of the x scores.

Computation of the Regression Equations (67:25)

$$Y_c = mX + K$$

$$m = \frac{N\Sigma xy - \Sigma x \Sigma y}{N \cdot x^2 - (\Sigma x)^2}$$

$$K = \bar{Y} - m\bar{X}$$

m = regression coefficient

Y_c = predicted value of y

X = observed value of x

K = intercept on the y axis

N = number of scores

$\bar{Y}$ = mean of the y scores

$\bar{X}$ = mean of the x scores.

Computation of the correlation Coefficients (46:139)

$$r = \frac{\frac{\Sigma xy}{N} - \frac{\Sigma x}{N} \cdot \frac{\Sigma y}{N}}{S_x S_y}$$

r = correlation coefficient

Σx = the sum of the values for each observation in parameter x

Σy = the sum of the value for each observation in parameter y

N = the number of paired observations

S_x = standard deviation of parameter x

S_y = standard deviation of parameter y

Computation of the Analysis of Variance (46:280-288)

A. Sums of Squares

1. Correction Term (C) = $\frac{(\Sigma x_1 + \Sigma x_2 + \ldots + \Sigma x_n)^2}{N}$

2. Total Sum of Squares (SS_T) = $\Sigma x_1^2 + \Sigma x_2^2 + \ldots + \Sigma x_k^2 - C$

3. Sum of Squares Among Groups (SS_B) =

$$\frac{(\Sigma x_1)^2}{N_1} + \frac{(\Sigma x_2)^2}{N_2} + \ldots + \frac{(\Sigma x_k)^2}{N_n} - C$$

4. Sum of Squares Within Groups (SS_W) = Total SS - Among Groups SS

B. Analysis of Variance

Source of Variation	df	Sum of Squares	Mean Square (Variance)
Among Groups	K-1	SS_B	$\frac{SS_B}{K-1}$
Within Groups	N-K	SS_W	$\frac{SS_W}{N-K}$
Total	N-1	SS_T	

$F = \frac{Variance_B}{Variance_W}$ Critical F ratios from Garrett (46:451-454)

Σx_1 = Sum of the group 1 scores

Σx_2 = Sum of the group 2 scores

N = Total number of subjects

N_1 = Number of subjects in group 1

K = Number of groups.

Computation of the Duncan's New Multiple Range Test Modified by Kramer for Unequal Numbers of Subjects (62)

Only the 0.01 level of confidence was accepted as indicative of significance since, according to Edwards (40:140), "the k-mean protection level for the multiple range test is given by $(1-\alpha)^{k-1}$. Thus, with [5] means and α=.01, the protection level is $(1-.01)^{5-1}$ which equals [81] per cent, which is the minimum probability of finding no erroneous significant differences between the [5] means." With α = .01 the protection level is 96 per cent. The .05 level was, therefore, considered not adequate protection against Type 1 errors in this study.

A. Analysis of Variance

Source	df	Mean Square	F
Among Groups	2	1245.54	16.96 ($p<0.01$)
Within Groups (error)	496	73.45	
Total	498		

B. $S = \sqrt{73.45} = 8.57 = \sqrt{\text{error mean square}}$

C. Significant Studentized Ranges for a 1% Duncan Multiple Range ($z_{p,120}$ or $z_{p,\infty}$)

$n_2 = 496$

p	2	3	
n_2=120	3.70	3.86	
$n_2=\infty$	3.64	3.80	(From Table, 40:374)

D. Appropriate Significant Range Factors ($R'_p = S\, z_{p,120}$ or $S\, z_{p,\infty}$)
(Shortest Significant Ranges)

p:	(2)	(3)
$R'_{p,120}$	31.10	33.08
$P'_{p,\infty}$	31.19	32.57

E. Duncan's Test--Group Means Ranked in Ascending Order

		1	2	3		
	n	134	243	122	Shortest Significant Ranges	
	$\bar{X}$	42.35	46.13	48.47	120 d.f.	d.f.
1.	42.35		49.67	69.16	R'_2 31.70	31.19
2.	46.13			29.81	R'_3 33.08	32.57

Means subtended by same line are not significantly different at $p = 0.01$ level.

F. Test:

In order for $(\bar{X}_3 - \bar{X}_1)$ to be significant

$$(\bar{X}_3 - \bar{X}_1)\sqrt{\frac{2\ n_1 n_3}{n_1+n_3}}$$

$$\bar{X}_3 - \bar{X}_1 \sqrt{\frac{2(134)(122)}{256}} = 69.16$$

must exceed R'_3

For $(\bar{X}_3 - \bar{X}_2)$ to be significant

$$(\bar{X}_3 - \bar{X}_2)\sqrt{\frac{2n_2 n_3}{n_2+n_3}} = 29.81$$

must exceed R'_2

etcetera.

Computation of the Significance of the Difference Between Two Means With $N_1 \neq N_2$ But with Homogeneity of Variance (40:92-94)

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_{\bar{x}_1 - \bar{x}_2}} \qquad S_{\bar{x}_1 - \bar{x}_2} = \sqrt{\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}} \qquad N_1 + N_2 - 2 \text{ d.f.}$$

where:

$\bar{X}_1$ = mean of the scores in group 1

$\bar{X}_2$ = mean of the scores in group 2.

$S_{\bar{x}_1 - \bar{x}_2}$ = standard error of the difference between the means

S_1^2 = variance of the scores in group 1.

S_2^2 = variance of the scores in group 2

N_1 = number of subjects in group 1

N_2 = number of subjects in group 2

Computation of the Test for the Homogeneity of Variance (40:105)

$$F = \frac{S_2^2}{S_1^2}$$

Where

S_2^2 = larger variance

S_1^2 = smaller variance

N_2 - 1 d.f.

N_1 - 1 d.f.

Computation of the Inter- and Intra-Individual Variance and the Test-Retest Reliability Coefficient (75)

$$S_X^2 - S_t^2 = S_{w/i}^2$$

$$S_t^2 = \text{Cov}\,(x, y)$$

$$S_X^2 = \frac{S_x^2 + S_y^2}{2}$$

$$r_{xx} = \frac{S_t^2}{\sqrt{S_x^2 \cdot S_y^2}}$$

$$S_t^2 = \frac{\Sigma xy}{n} - \left(\frac{\Sigma x}{n}\right)\left(\frac{\Sigma y}{n}\right)$$

$$S_x^2 = \frac{\Sigma x^2}{n} - \left(\frac{\Sigma x}{n}\right)^2$$

$$S_y^2 = \frac{\Sigma y^2}{n} - \left(\frac{\Sigma y}{n}\right)^2$$

S_X^2 = total variance

S_t^2 = Inter-individual variance

$S_{w/i}^2$ = Intra-individual variance (contains error variance)

S_x^2 = Variance of the scores in group x

S_y^2 = Variance of the scores in group y

r_{xx} = Reliability Coefficient

Σx = sum of the scores in test 1

Σy = sum of the scores in test 2

Σx^2 = sum of the squares of each score in test 1

Σy^2 = sum of the squares of each score in test 2

APPENDIX D

STATISTICAL TREATMENT OF SPECIFIC ANALYSES

RELATIONSHIP BETWEEN WEIGHT, HEIGHT AND PREDICTED MAXIMAL OXYGEN INTAKE IN l/min. AS INDICATED BY THE SIMPLE AND FIRST ORDER PARTIAL CORRELATIONS

Age	n	Wt. vs Ht.	MVO_2 l/min vs Ht.	MVO_2 l/min vs Wt.	MVO_2 l/min vs Wt.·Ht.	MVO_2 l/min vs Ht.·Wt.
MALES						
15	62	0.62[a]	0.40[a]	0.49[a]	0.34[a]	0.13
16	146	0.46[a]	0.17[b]	0.27[a]	0.22[a]	0.05
17	162	0.48[a]	0.30[a]	0.38[a]	0.29[a]	0.14
18	82	0.50[a]	0.24[b]	0.47[a]	0.41[a]	0.01
19	36	0.53[a]	0.53[a]	0.39[a]	0.15	0.42[b]
14-21	499	0.53[a]	0.30[a]	0.40[a]	0.30[a]	0.11
FEMALES						
15	78	0.40[a]	0.18	0.43[a]	0.40[a]	0.01
16	152	0.46[a]	0.10	0.30[a]	0.29[a]	-0.04
17	132	0.47[a]	0.28[a]	0.37[a]	0.28[a]	0.13
18	39	0.49[a]	0.33[b]	0.45[a]	0.35[b]	0.14
19	9	0.60	0.14	0.16	0.05	0.10
14-21	417	0.47[a]	0.05	0.31[a]	0.31[a]	0.05

a significant at p = 0.01 level
b significant at p = 0.05 level

ANALYSIS OF VARIANCE

AGE DIFFERENCES

MALES MVO_2 (ml/kg/min)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Among Groups	333.19	4	83.2975	1.065
Within Groups	37,789.22	483	78.2386	
Total	38,122.41	487		

MALES MVO_2 l/min

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Among Groups	2.582	4	0.6458	1.905
Within Groups	163.696	483	0.3389	
Total	166.278	487		

MALES WEIGHT (kgm)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Among Groups	3,237.55	4	809.39	9.312
Within Groups	41,980.26	483	86.92	
Total	45,217.81	487		

ANALYSIS OF VARIANCE

AGE DIFFERENCES

MALES HEIGHT (cms)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Among Groups	745.1	4	186.275	3.662
Within Groups	24,567.1	483	50.864	
Total	25,312.2	487		

ANALYSIS OF VARIANCE

ACTIVITY STATUS (Active, Mod.Active, Not Active)

MALES MVO_2 (Ml/kg/min)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Among Groups	2,491.08	2	1,245.54	16.96
Within Groups	36,431.39	496	73.45	
Total	38.922.47	498		

MALES MVO_2 (l/min)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Among Groups	15.11	2	7.055	22.47
Within Groups	155.52	496	0.314	
Total	170.63	498		

MALES BODY WEIGHT (kg)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Among Groups	378.47	2	189.235	2.04
Within Groups	46,071.96	496	92.887	
Total	46,450.43	498		

MALES HEIGHT (cms)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Among Groups	291.5	2	145.75	2.79
Within Groups	25,899.8	496	52.2	
Total	26,191.3	498		

t-Test

BIKE RIDERS VS NON BIKE RIDERS

MALES MVO_2 (ml/kg)

$\bar{X}_{riders} = 45.80$ $\quad S^2 = 66.84$ $\quad n = 73$

$\bar{X}_{non\ riders} = 45.66$ $\quad S^2 = 80.32$ $\quad n = 426$

$$S_{\bar{X}_r - \bar{X}_n} = \sqrt{\frac{66.84}{73} + \frac{80.32}{426}} = 1.051$$

$$t = \frac{0.14}{1.051} = 0.133 \qquad 497 \text{ d.f.}$$

variances not significantly different

MALES MVO_2 (l/min)

$\bar{X}_{riders} = 2.81$ $\quad S^2 = 0.2941$ $\quad n = 73$

$\bar{X}_{non\ riders} = 2.97$ $\quad S^2 = 0.3482$ $\quad n = 426$

$$S_{\bar{X}_r - \bar{X}_n} = \sqrt{\frac{0.2941}{73} + \frac{0.3482}{426}} = 0.0696$$

$$t = \frac{-0.16}{0.0696} = -2.299$$

Variances not significantly different.

MALES WEIGHT (kg)

$\bar{X}_{riders} = 62.07$ $\quad S^2 = 90.59$ $\quad n = 73$

$\bar{X}_{nonriders} = 65.82$ $\quad S^2 = 91.89$ $\quad n = 426$

$$S_{\bar{X}_r - \bar{X}_n} = \sqrt{\frac{90.59}{73} + \frac{91.89}{426}} = 1.207$$

$$t = \frac{-3.75}{1.207} = -3.107$$

Variances not significantly different

t-Test

BIKE RIDERS VS NON BIKE RIDERS

MALES HEIGHT (cms)

$\bar{X}_{riders} = 173.7$ $S^2 = 48.44$ $n = 73$

$\bar{X}_{non\ riders} = 175.4$ $S^2 = 53.07$ $n = 426$

$$S_{\bar{X}_r - \bar{X}_n} = \sqrt{\frac{48.44}{73} + \frac{53.07}{426}} = 0.888$$

$$t = \frac{-1.7}{0.888} = -1.914$$

Variances not significantly different

ANALYSIS OF VARIANCE

AGE DIFFERENCES

FEMALES MVO_2 (ml/kg/min)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Among Groups	280.53	4	70.13	1.29
Within Groups	22,081.96	405	54.52	
Total	22,362.49	409		

FEMALES MVO_2 (l/min)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Among Groups	0.93	4	0.2325	1.33
Within Groups	71.05	405	0.1754	
Total	71.98	409		

FEMALES BODY WEIGHT (kgm)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Among Groups	285.03	4	71.258	1.258
Within Groups	22,938.48	405	56.64	
Total	23,223.51	409		

FEMALES HEIGHT (cms)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Among Groups	112.1	4	28.025	0.733
Within Groups	15,477.9	405	38.217	
Total	15,590.0	409		

ANALYSIS OF VARIANCE

ACTIVITY STATUS (Active, Mod.Active, Not Active)

FEMALES MVO_2 (ml/kg/min)

Sources of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Among Groups	508.22	2	254.11	4.77
Within Groups	22,066.14	414	53.30	
Total	22,574.36	416		

FEMALES MVO_2 (l/min)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Among Groups	2.43	2	1.215	4.02
Within Groups	124.87	414	0.302	
Total	127.30	416		

FEMALES WEIGHT (kgm)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Among Groups	92.78	2	46.39	0.82
Within Groups	23,431.91	414	56.60	
Total	23,524.69	416		

FEMALES HEIGHT (cms)

Sources of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Among Groups	267.0	2	133.5	3.52
Within Groups	15,688.4	414	37.9	
Total	15,955.4	416		

t-Test

BIKE RIDERS VS NON BIKE RIDERS

FEMALES MVO_2 (ml/kg/min)

$\bar{X}_{riders} = 38.88$ $S^2 = 60.09$ $n = 80$

$\bar{X}_{non\ riders} = 36.92$ $S^2 = 52.31$ $n = 337$

$$S_{\bar{X}_r - \bar{X}_n} = \sqrt{\frac{60.09}{80} + \frac{52.31}{337}} = 0.952$$

$$t = \frac{1.96}{0.952} = 2.059$$

Variances not significantly different

FEMALES MVO_2 (l/min)

$\bar{X}_{riders} = 2.16$ $S^2 = 0.1920$ $n = 80$

$\bar{X}_{non\ riders} = 2.02$ $S^2 = 0.1692$ $n = 337$

$$S_{\bar{X}_r - \bar{X}_n} = \sqrt{\frac{0.1920}{80} + \frac{0.1692}{337}} = 0.0539$$

$$t = \frac{0.14}{0.0539} = 2.597$$

Variances not significantly different

FEMALES WEIGHT (kgm)

$\bar{X}_{riders} = 55.85$ $S^2 = 51.23$ $n = 80$

$\bar{X}_{non\ riders} = 55.10$ $S^2 = 57.86$ $n = 337$

$$S_{\bar{X}_r - \bar{X}_n} = \sqrt{\frac{51.23}{80} + \frac{57.86}{337}} = 0.901$$

$$t = \frac{0.75}{0.901} = 0.832$$

Variances not significantly different.

t-Test

BIKE RIDERS VS NON BIKE RIDERS

FEMALES HEIGHT (cms)

$\bar{X}_{riders} = 163.0$ $\quad S^2 = 36.78$ $\quad n = 80$

$\bar{X}_{non\ riders} = 162.8$ $\quad S^2 = 38.83$ $\quad n = 337$

$$S_{\bar{X}_r - \bar{X}_n} = \sqrt{\frac{36.78}{80} \quad \frac{38.83}{337}} = 0.758$$

$$t = \frac{0.2}{0.758} = 0.264$$

Variances not significantly different.

APPENDIX E

CALIBRATION OF EQUIPMENT

Beckman E-2 Oxygen Analyzer

A correction factor for some of the Beckman Oxygen Analyzer readings was established by means of a regression equation calculated from the values of gas analyzed on a Scholander Micrometer Gas Analyzer and on the Beckman analyzer, when it was found that the commercial N_2 used in calibrating the instrument was impure.

The regression equation was:

$y = 0.893 x - 2.22$

y = the corrected percentage of oxygen

X = the Beckman E-2 analyzer reading in per cent

later in the study new calibration nitrogen was obtained and when analyzed on a Scholander Micrometer Gas Analyzer was found to be pure. The correction factor was no longer needed.

Monark Bicycle Ergometer

Calibration of the sinus balance of the bicycle ergometer was carried out according to the technique proposed by Astrand (16). A set of stainless steel weights, #750 Class S-1 Serial No. 741458, were used in the calibration which was found to be within one per cent of the correct value over the resistance range used.

Volumeter

An American Meter Company Gas Meter #802 was used in determining the volume of expired air. When checked against volume readings from two Tissot Spirometers it was found that the meter readings exceeded the actual volumes of air expired. On the basis of the Tissot readings, a regression equation was calculated. The equation was:

$y = 0.22770 + 0.943099X$

y = corrected volume

X = meter reading volume.

The corrected meter volume readings included the volume of gas lost in the CO_2 and O_2 analysis since the flow rate through the Beckman analyzer was 400 ml of gas per minute.

Godart Capnograph (Infra-red Carbon Dioxide Analyzer)

This instrument, when checked with the Scholander Micrometer Gas Analyzer values was found to be accurate.

APPENDIX F

SCORE SHEETS

ASTRAND BICYCLE ERGOMETER TEST

DATE OF TEST _____

NAME _____ SEX _____ DATE OF BIRTH _____

ADDRESS _____ HT. _____ WT. _____

SCHOOL _____ GRADE _____

RESIDENCE - Urban (over 5,000) _____

Rural (under 1,000) _____ (1000-5000) ___ Farm __

SMOKE: Yes ____ No _____

Do you ride a Bicycle? Yes ___ No ___ Would you be tested again? Yes ___ No ____

Gr. 12 Do you plan to attend U. of A. in Sept. 1964? Yes ___ No ___

Do you participate in the regular P.E. Program ? Yes ___ No ___

DATA

TIME	TIME	TABLE	WORK
Minutes	30 Bts.	Bts/min	Load

Resting Pulse _____ Steady State Pulse _____ Pred. Max. O_2 _____

REMARKS:

Name _____

Date _____

t = _____ ^{o}C

B.P. = _____ mm. Hg

Factor = _____

FeO_2 = _____ x $\frac{2.5}{100}$ = _____ F_1O_2 = 20.94

FeO_2 = _____ (corr.) F_1CO_2 = 00.03

$FeCO_2$ = _____ F_1N_2 = 79.03

FeN_2 = _____

V_EATPS = _____ l.min.

V_ESTPD = _____ x _____ = _____ l.min.

V_ISTPD = _____ x _____ = _____

VO_2 = (_____ x 2094) - (_____ x _____) = _____ l./min.

VCO_2 = (_____ x ____) - (_____ x .003) = _____ l./min.

R. Q.= _____

Name: _____ Date of Birth: _____ Height: _____ in. Sex: _____

Previously tested at _____ High School

Submaximal VIO_2 Test

Date _____

Weight _____ lbs. _____ kgm.

Resting Pulse Rate _____ b/min.

Time (Min)	Heart Rate			Work Load (K.p.m)
	Palpation		ECG	
	Time (sec)	H.R b/min.	b/min	
1				
2				
3				
4				
5				
6				
7				
8				
Steady state				

Predicted VIO_2 _____ l.

_____ ml./Kgm

Maximal VIO_2 Test

Date _____

Weight _____ lbs. _____ Kgm.

Resting Pulse Rate _____ b/min.

Remarks:

Work Load Kpm	HEART RATES												ANALYSIS				DUPLICATE		
	PALPATION						ECG												
	1	2	3	4	5	6	1	2	3	4	5	6	CO_2	O_2	Vol.	VIO_2	CO_2	O_2	VIO_2

Actual VIO_2 _____ l.

_____ ml./kgm

Steady State: Heart Rate _____ b./min.

Work Load _____ kp.m.

Predicted VIO_2 from Maximal Test: _____ l.

_____ ml./kg

Name _____ Date of Exam _____ Height _____ in. Sex _____

Maximum Testing at _____ mph Grade

Submaximal VO2 Test

Date _____

Weight _____ lbs _____ kgm

Resting Pulse Rate _____ b/min

Minimal VO2 Test

Date _____

Weight _____ lbs _____ kgm

Resting Pulse Rate _____ b/min

Remarks:

Time	Speed	Grade	Work	Pulse
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Maximal VO2 _____

_____ Method

Physical Fitness Index _____

Name _____ HEART RATE _____ Duration

Load _____ Pulse Duration _____

Min 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 mm ss

Recovery VO2 _____ l

_____ Method

Physical Fitness Index _____

Steady State Heart Rate _____ b/min

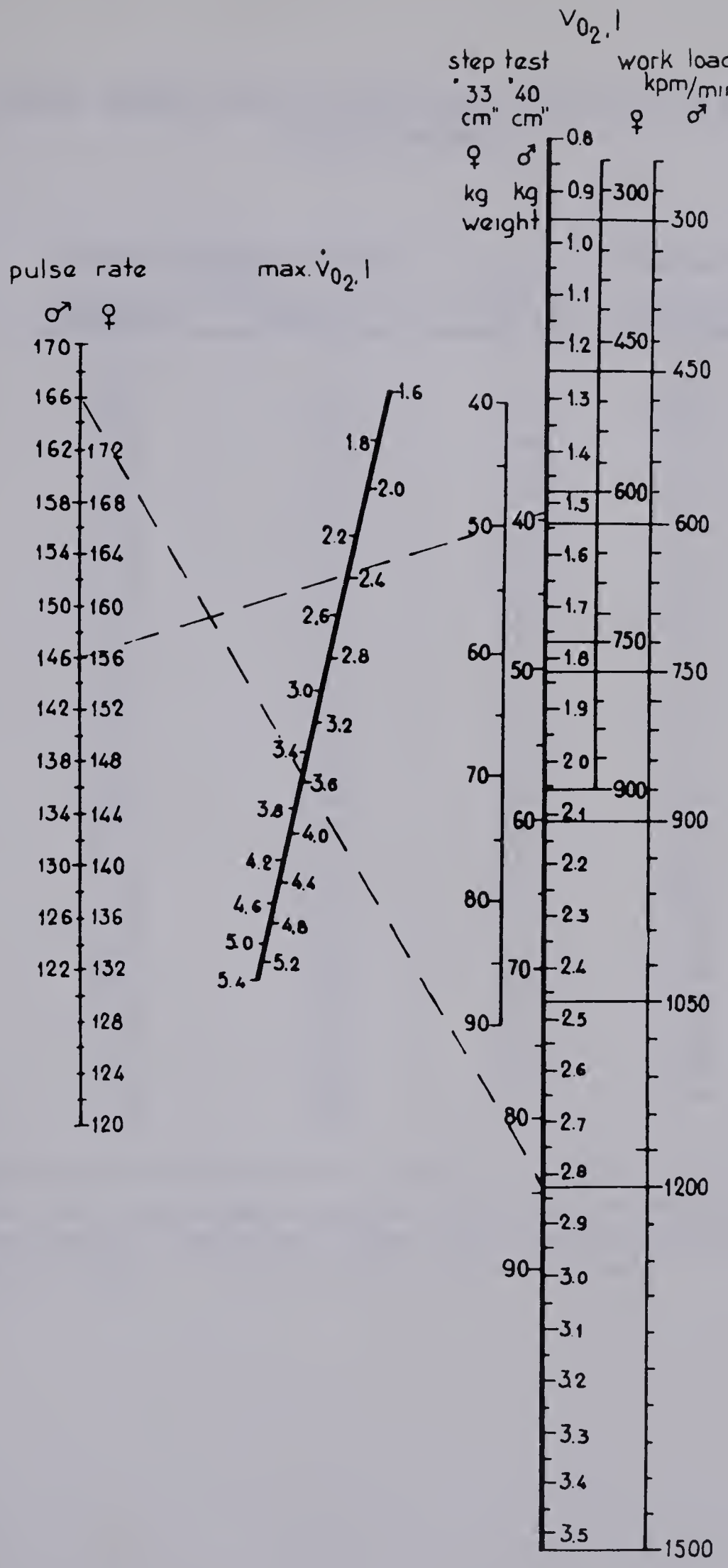
Work Load _____ kgm

Maximal VO2 Index _____ l

Maximal Test _____ Method

APPENDIX G

RAW SCORES



The Åstrand nomogram for the calculation of aerobic work capacity from submaximal pulse rates and O_2-uptake values. (*From I. Åstrand, Acta Physiol. Scand., Suppl.* **49,** 169, 1960. *Reproduced by permission of the publisher.*)

PREDICTION OF MAXIMAL OXYGEN UPTAKE FROM PULSE RATE AND WORK LOAD ON A BICYCLE ERGOMETER

MALES

Working Pulse	Maximal Oxygen Uptake (l/min) kpm/min	kpm/min	Working Pulse	Maximal Oxygen Uptake (l/min) kpm/min	kpm/min
120	3.50[a]	4.80	146	2.40	3.30
121	3.45	4.70	147	2.38	3.28
122	3.40	4.62	148	2.35	3.24
123	3.35	4.60	149	2.33	3.20
124	3.30	4.54	150	2.30	3.15
125	3.20	4.43	151	2.28	3.12
126	3.18	4.35	152	2.25	3.08
127	3.14	4.30	153	2.22	3.64
128	3.10	4.20	154	2.20	3.00
129	3.04	4.15	155	2.18	2.98
130	3.00	4.10	156	2.15	2.94
131	2.94	4.14	157	2.13	2.90
132	2.90	4.00	158	2.11	2.88
133	2.84	3.94	159	2.10	2.84
134	2.80	3.90	160	2.08	2.82
135	2.78	3.84	161	2.04	2.80
136	2.74	3.78	162	2.02	2.78
137	2.70	3.70	163	2.00	2.75
138	2.68	3.65	164	1.99	2.70
139	2.65	3.60	165	1.98	2.68
140	2.62	3.55	166	1.94	2.65
141	2.60	3.52	167	1.92	2.62
142	2.54	3.48	168	1.90	2.60
143	2.51	3.42	169	1.88	2.58
144	2.50	3.39	170	1.84	2.55
145	2.44	3.35			

[a]The above values were read directly from the nomogram (6) as were values for work loads not listed. Each value was multiplied by the factor 1.1 (16). (The correction factor for age.)

PREDICTION OF MAXIMAL OXYGEN UPTAKE FROM PULSE RATE AND WORK LOAD ON A BICYCLE ERGOMETER

FEMALES

Working Pulse	Maximal Oxygen Uptake (l/min) 300 kpm/min	450 kpm/min	600 kpm/min	Working Pulse	Maximal Oxygen Uptake (l/min) 300 kpm/min	450 kpm/min	600 kpm/min
120	2.58	3.35	4.10	146	1.63	2.15	2.64
121	2.50	3.30	4.00	147	1.61	2.13	2.62
122	2.50	3.20	3.90	148	16.0	2.10	2.58
123	2.40	3.15	3.85	149	1.55	2.07	2.55
124	2.40	3.10	3.80	150	1.53	2.04	2.50
125	2.34	3.04	3.70	151	1.50	2.00	2.48
126	2.30	2.98	3.60	152	1.50	1.98	2.45
127	2.24	2.90	3.54	153	1.46	1.95	2.40
128	2.20	2.85	3.52	154	1.45	1.93	2.38
129	2.15	2.78	3.44	155	1.42	1.92	2.35
130	2.10	2.75	3.40	156	1.40	1.90	2.32
131	2.07	2.70	3.35	157	1.38	1.87	2.30
132	2.03	2.67	3.25	158	1.35	1.85	2.27
133	2.00	2.63	3.20	159	1.34	1.82	2.24
134	2.00	2.60	3.18	160	1.31	1.80	2.22
135	1.95	2.55	3.12	161	1.30	1.78	2.20
136	1.92	2.50	3.05	162	1.28	1.75	2.18
137	1.90	2.45	3.00	163	1.25	1.72	2.15
138	1.84	2.40	2.97	164	1.23	1.71	2.12
139	1.81	2.38	2.92	165	1.21	1.70	2.10
140	1.80	2.34	2.84	166	1.20	1.68	2.08
141	1.77	2.30	2.80	167	1.17	1.65	2.05
142	1.75	2.28	2.78	168	1.16	1.63	2.03
143	1.72	2.25	2.75	169	1.15	1.61	2.00
144	1.70	2.20	2.72	170	1.13	1.60	1.99
145	1.64	2.18	2.70				

LABORATORY EXPERIMENT FEMALES n = 23

Name	Yrs-Mos	Weight (kg) T_1	Weight (kg) T_2	Steady State Heart Rate T_1	Steady State Heart Rate T_2	MVO_2 (l/min) T_1	MVO_2 (l/min) C	Pred. MVO_2 (l/min) T_2	Pred. MVO_2 (l/min) C	MVO_2 ml/kg/min T_1	MVO_2 ml/kg/min T_2	Work Load (kpm/min)
Bowker	14-1	64.86	63.32	152	147	1.50	1.65	1.62	1.78	25.44	28.11	300
Moore	14-9	54.88	54.43	142	144	1.75	1.93	1.74	1.91	35.17	35.09	300
Mould	15-2	69.63	69.85	152	150	1.50	1.65	1.53	1.68	23.83	24.05	300
Oslie	15-3	54.43	53.98	142	149	1.75	1.93	1.55	1.71	35.46	31.68	300
Whitlock	15-5	48.53	48.08	165	165	1.22	1.34	1.22	1.34	27.61	27.87	300
Stewart	15-6	68.15	68.15	129	137	2.18	2.40	1.91	2.10	35.22	30.81	300
Peets	15-8	51.71	51.71	149	147	1.55	1.71	1.62	1.78	33.07	34.42	300
Edge, H	15-9	56.70	57.15	144	159	1.70	1.87	1.34	1.47	32.98	25.72	300
McIntyre	16-0	57.15	56.25	142	131	1.76	1.94	2.07	2.28	33.95	40.53	300
Allen	16-3	59.42	58.06	167	153	1.67	1.84	1.95	2.15	30.97	37.03	450
McGregor	16-8	54.43	55.24	142	146	1.75	1.93	1.63	1.79	35.46	32.40	300
Irvine	16-8	59.19	58.29	134	130	2.00	2.20	2.10	2.31	37.17	39.63	300
Neville	16-11	60.56	61.92	128	137	2.23	2.45	1.90	2.09	40.46	33.75	300
White	17-0	66.69	66.22	138	139	1.85	2.04	1.81	1.99	30.59	30.05	300
Gall	17-2	47.63	47.13	159	163	1.34	1.47	1.26	1.39	30.86	29.49	300
Rosen	17-3	49.44	50.35	150	153	1.53	1.68	1.46	1.61	33.98	31.98	300
Edge, M.	17-3	48.99	48.99	154	150	1.46	1.61	1.53	1.68	32.86	34.29	300
McKilligan	17-4	72.57	72.12	140	137	1.81	1.99	1.90	2.09	27.42	28.98	300
Bolstlar	17-4	53.07	52.16	161	158	1.30	1.43	1.35	1.49	28.83	28.57	300
Kaspar	17-6	50.35	51.47	151	154	1.50	1.65	1.46	1.61	32.77	31.46	300
Dawson	17-11	64.41	64.41	142	129	1.76	1.94	2.18	2.40	30.12	38.80	300
Coyne	18-7	70.31	68.49	129	149	2.15	2.37	1.55	1.71	33.71	24.97	300
Wendt	18-7	72.57	72.57	146	141	1.63	1.79	1.77	1.95	24.67	26.87	300

LABORATORY EXPERIMENT MALES n = 23

Name	Age Yrs-Mos	Weight (kg) T_1	Weight (kg) T_2	Steady State Heart Rate T_1	Steady State Heart Rate T_2	MVO_2 (l/min) T_1	MVO_2 (l/min) C	Pred. T_2	Pred. C	MVO_2 ml/kg/min T_1	MVO_2 ml/kg/min T_2	Work Load (kpm/min)
Allen	15-6	61.92	60.78	154	153	2.21	2.43	2.22	2.44	39.24	40.14	600
Fournier	15-7	67.58	65.77	125	125	3.20	3.52	3.20	3.52	52.09	53.52	600
Evans	15-8	64.64	64.64	128	144	3.12	3.43	2.51	2.76	53.06	42.70	600
Boychuk	16-4	63.73	63.28	173	166	1.72	1.89	1.94	2.13	31.23	33.66	600
Brotherston	16-5	73.03	72.12	125	124	3.25	3.58	3.33	3.66	49.02	50.75	600
Fuller	16-5	70.76	70.76	141	146	3.52	3.87	3.30	3.63	54.69	51.30	900
Winter	16-7	64.86	64.86	150	161	2.30	2.53	2.06	2.27	39.01	35.00	600
Hohnstein	16-7	59.87	59.87	139	148	2.65	2.92	2.35	2.59	48.77	43.26	600
Schwartzberg	16-7	60.78	59.65	133	136	2.87	3.16	2.74	3.01	52.14	50.46	600
Currie	16-10	72.57	71.67	143	140	2.51	2.76	2.62	2.88	38.03	40.18	600
Stewart	17-0	57.15	58.51	153	135	2.22	2.44	2.78	3.06	42.69	52.30	600
Jones	17-2	62.37	62.60	153	138	2.22	2.44	2.68	2.95	39.12	47.12	600
Feldman	17-2	73.94	73.94	142	143	2.57	2.83	2.53	2.78	38.27	37.60	600
Bradshaw	17-3	63.50	63.50	137	132	2.70	2.97	2.92	3.21	46.77	50.55	600
Bentley	17-4	64.86	65.32	136	142	2.76	3.04	2.51	2.76	46.87	42.25	600
Ford	17-4	63.16	62.26	124	124	3.30	3.63	3.30	3.63	57.47	58.30	600
MacLean	17-4	53.52	53.07	136	140	2.76	3.04	2.62	2.88	56.80	54.27	600
Fox	17-6	75.98	75.75	149	147	2.33	2.56	2.39	2.63	33.69	34.72	600
Boyes	17-6	79.83	78.47	136	132	2.74	3.01	2.92	3.21	37.71	40.91	600
Prinsen	17-8	60.78	60.33	157	151	2.13	2.34	2.88	2.51	38.50	41.60	600
Bouthillier	17-8	55.34	55.34	144	141	2.50	2.75	2.60	2.86	49.69	51.68	600
McNeil	17-10	58.97	58.51	160	160	2.08	2.29	2.08	2.29	38.83	39.14	600
Cadger	18-0	73.26	72.69	142	142	3.50	3.85	3.48	3.83	52.55	52.69	900

KEY TO IBM PRINT OUT OF RAW SCORES

a - Subject identification

b - Sex 1 - female 2 - male

c - Age (months)

d - Weight (kilograms) - insert decimal after the second digit, e.g. 60.33

e - Height (centimeters) - insert decimal after the third digit, e.g. 176.5

f - Predicted Maximal Oxygen Intake(liters per minute) - insert decimal after the first digit, e.g., 1.28

g - Predicted Maximal Oxygen Intake (milliliters per kilogram per minute)- insert decimal after the second digit, e.g., 21.15

h - Pre-exercise heart rate

i - Does subject smoke? 1 - Yes 0 - No

j - Activity status 0 - Highly Active 1 - Moderately Active
2 - Not Active

k - Does subject ride bike? 1 - Yes 0 - No

FIELD EXPERIMENT Females n = 417

a	b	c	d	e	f	g	h	i	j	k
30032	1	187	4581	1638	192	4259	096	1	1	0
10018	1	188	5942	1715	220	3703	084	1	1	0
24030	1	191	5942	1702	220	3703	083	1	0	0
35029	1	189	5554	1588	252	4159	088	1	1	0
02004	1	191	6123	1626	239	3898	080	1	1	0
22016	1	184	6895	1702	305	4419	064	1	2	0
42005	1	231	6260	1664	159	2442	124	1	1	0
35037	1	232	4763	1562	220	4619	084	1	2	0
31021	1	228	6758	1702	329	4866	074	1	2	0
24025	1	218	5126	1613	147	2875	124	1	2	0
19025	1	222	4743	1549	160	3363	119	1	2	0
25022	1	219	5942	1626	163	2740	096	1	2	0
32017	1	216	6305	1702	179	2844	088	1	1	0
40011	1	218	5761	1626	191	3322	100	1	1	0
01019	1	218	6305	1676	219	3472	092	1	2	0
02005	1	219	5443	1613	219	4022	101	1	1	0
47005	1	218	5579	1600	223	4003	084	1	1	0
02006	1	225	7756	1638	251	3254	092	1	2	0
21029	1	205	5035	1473	131	2599	117	1	2	0
31020	1	202	4853	1613	193	3967	072	1	2	0
16019	1	199	7214	1626	198	2746	103	1	1	0
11009	1	198	5443	1600	198	3638	068	1	2	0
23033	1	201	6123	1715	199	3252	110	1	1	0
22023	1	201	5080	1638	202	3984	112	1	2	0
20024	1	198	6123	1634	214	3467	090	1	1	0
11007	1	196	5670	1626	213	3783	088	1	1	0
24020	1	192	6305	1638	220	3469	088	1	2	0
19018	1	197	5171	1626	220	4259	080	1	2	0
20029	1	200	5897	1651	222	3708	106	1	1	0
51006	1	201	6577	1613	227	3445	092	1	1	0
20026	1	200	6486	1651	228	3510	080	1	2	0
35038	1	193	4899	1676	237	4328	072	1	1	0
22022	1	193	9525	1740	240	2518	111	1	2	0
23038	1	192	6260	1753	242	3865	080	1	2	0
19017	1	194	5080	1626	248	4872	092	1	2	0
32020	1	199	5351	1727	260	4436	072	1	0	0
01014	1	201	6577	1753	263	3997	080	1	2	0
24029	1	193	5987	1676	263	4465	056	1	0	0
35023	1	202	7620	1651	270	3609	099	1	1	0
52001	1	201	5670	1651	297	3230	084	1	2	0
11011	1	209	4989	1524	270	3512	076	1	2	0
48004	1	209	7548	1575	300	4147	060	1	1	0
22020	1	244	5443	1575	196	3577	096	1	2	0
10016	1	203	6033	1765	120	2113	143	1	2	0
10020	1	201	4989	1600	143	2867	090	1	2	0
08008	1	192	5987	1702	153	2554	104	1	2	0
40007	1	201	5392	1765	158	2960	092	1	1	0
41002	1	193	4989	1600	160	3308	098	1	1	0
22028	1	203	4853	1587	176	3517	096	1	2	0
21032	1	196	5035	1600	177	3518	089	1	1	0
24021	1	200	5080	1651	182	3575	092	1	2	0

21011	1	199	6350	1727	197	2948	092	1	1	0
24026	1	199	5534	1626	187	3279	074	1	2	0
24027	1	197	5030	1638	187	3714	124	1	2	0
21027	1	203	4534	1549	187	4106	072	1	2	0
24024	1	202	4354	1549	189	4345	126	1	1	0
22031	1	203	5210	1638	190	3671	112	1	1	0
22032	1	204	4670	1613	210	4499	080	1	1	0
23042	1	212	4713	1600	211	4481	084	1	1	0
19021	1	204	5352	1650	217	4049	084	1	2	0
17008	1	210	5210	1588	217	4155	078	1	1	0
35028	1	206	4581	1650	218	4704	103	1	1	0
16026	1	211	5897	1576	219	3713	089	1	2	0
30030	1	214	5534	1727	228	4115	084	1	2	0
25020	1	211	6350	1651	230	3673	113	1	2	0
61001	1	213	5352	1676	230	4357	076	1	2	0
15015	1	205	5670	1676	250	4404	088	1	2	0
21030	1	211	7167	1702	253	3530	093	1	1	0
35040	1	205	6260	1702	257	4112	096	1	2	0
09008	1	205	5534	1676	267	4850	088	1	0	0
10024	1	211	4713	1626	160	5454	076	1	2	0
33028	1	204	6985	1689	177	2556	089	1	2	0
15010	1	204	4969	1626	177	3550	084	1	2	0
35024	1	211	4853	1713	177	3650	080	1	2	0
29033	1	214	5488	1651	186	3367	101	1	2	0
65004	1	215	5035	1676	186	3693	096	1	1	0
20028	1	205	5897	1626	187	3171	096	1	2	0
21025	1	215	5352	1651	189	3535	082	1	2	0
19022	1	206	5035	1626	189	3758	084	1	1	0
31021	1	205	5851	1664	193	3290	104	1	2	0
31019	1	207	4763	1549	195	4041	064	1	2	0
40010	1	215	6123	1778	198	3254	086	1	2	0
10017	1	208	5715	1676	201	3522	080	1	2	0
29025	1	207	5897	1651	202	3432	129	1	1	0
14018	1	190	5987	1600	177	2958	100	1	1	1
35006	1	190	6532	1664	228	3486	100	1	1	1
29029	1	191	5398	1676	314	3808	064	1	0	1
22021	1	219	6123	1651	261	4258	084	1	0	1
73005	1	220	6350	1715	289	4556	066	1	0	1
07025	1	195	5398	1715	206	3810	104	1	1	1
07029	1	209	5625	1676	278	4948	064	1	1	1
63005	1	205	6123	1702	297	4851	088	1	0	1
40004	1	195	5715	1626	188	3291	076	1	2	1
20031	1	214	7214	1715	214	2944	100	1	2	1
14022	1	215	5942	1664	218	3665	072	1	1	1
23030	1	210	5761	1715	220	3819	088	1	2	1
11010	1	205	5670	1588	233	4113	076	1	1	1
56004	1	212	5035	1613	189	3758	072	1	0	1
22037	1	183	6669	1702	156	2342	128	0	1	0
23034	1	184	5942	1600	156	2629	137	0	1	0
13005	1	186	5262	1588	161	3053	096	0	1	0
25023	1	186	5534	1588	165	2982	092	0	0	0
01009	1	187	5120	1549	174	3390	080	0	1	0
76001	1	185	4491	1575	180	4017	062	0	1	0
23037	1	186	4713	1651	182	3897	080	0	1	0
35033	1	185	4944	1549	187	3703	091	0	1	0
37009	1	181	5942	1626	188	3166	096	0	1	0
08006	1	190	5486	1689	188	3428	096	0	1	0
35034	1	189	6804	1613	189	2781	060	0	1	0
30026	1	187	6350	1702	189	2980	135	0	1	0
23051	1	188	5987	1676	189	3160	094	0	1	0

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35039	1	197	5851	1536	191	3528	072	0	1	0
24041	1	198	5598	1549	199	3648	080	0	2	0
23035	1	193	5171	1575	195	3761	076	0	1	0
24039	1	197	4672	1613	197	4214	092	0	1	0
01013	1	200	5670	1756	198	3493	086	0	0	0
26026	1	196	5035	1613	198	3933	084	0	1	0
17012	1	194	6849	1626	199	2907	088	0	1	0
42002	1	200	5262	1664	199	3784	123	0	1	0
17014	1	199	5171	1575	201	3893	088	0	1	0
20025	1	203	5897	1676	202	3432	102	0	2	0
23046	1	203	4899	1626	202	4132	088	0	2	0
40006	1	200	7484	1753	204	2719	084	0	1	0
22026	1	200	5579	1626	204	3648	084	0	0	0
04007	1	202	4944	1651	204	4116	097	0	2	0
78003	1	203	4627	1575	206	4445	092	0	1	0
20023	1	196	5806	1689	208	3581	084	0	1	0
33026	1	199	4853	1626	209	4307	087	0	1	0
76004	1	200	5171	1638	211	4084	068	0	2	0
24034	1	194	5670	1638	212	3744	070	0	1	0
23032	1	197	4713	1549	213	4528	080	0	2	0
38011	1	202	5579	1664	215	3845	096	0	1	0
67002	1	203	5443	1664	215	3941	084	0	0	0
21024	1	198	5262	1626	218	4139	086	0	2	0
30028	1	197	6214	1676	219	3522	080	0	1	0
13004	1	194	5897	1638	220	3731	112	0	2	0
23031	1	194	6350	1651	227	3568	109	0	2	0
26022	1	197	4899	1575	228	4648	078	0	1	0
32019	1	192	5851	1626	234	4004	101	0	1	0
28008	1	195	5443	1689	234	4304	072	0	1	0
73003	1	192	5443	1549	237	4345	066	0	1	0
37007	1	193	6123	1727	239	3898	114	0	0	0
29034	1	192	5534	1626	240	4333	052	0	1	0
35027	1	193	4989	1638	240	4807	120	0	1	0
43004	1	193	4989	1638	240	4807	072	0	0	0
17013	1	197	4399	1549	241	3476	080	0	1	0
29023	1	199	4763	1626	242	3981	084	0	2	0
24032	1	197	5579	1676	245	4397	076	0	1	0
10021	1	201	5897	1626	248	4197	080	0	0	0
26025	1	200	5171	1562	248	4736	072	0	0	0
30038	1	203	6260	1626	251	4006	072	0	2	0
56003	1	192	5625	1575	251	4458	068	0	1	0
28009	1	198	5670	1638	257	4540	080	0	1	0
20021	1	203	6396	1689	263	4111	090	0	1	0
09006	1	201	6577	1727	264	4014	068	0	1	0
32014	1	203	5443	1676	280	3255	068	0	0	0
29024	1	201	6713	1727	292	4343	080	0	2	0
69003	1	200	4989	1537	311	6217	064	0	1	0
25021	1	183	3583	1549	125	3500	076	0	1	0
35031	1	190	4627	1549	129	2782	092	0	1	0
23048	1	191	4989	1638	133	2668	148	0	1	0
12004	1	190	5443	1626	136	2536	113	0	1	0
25025	1	191	5216	1626	141	2679	090	0	1	0
23039	1	181	5216	1575	143	2741	100	0	1	0
20020	1	183	4554	1575	143	3141	068	0	1	0
31028	1	188	4443	1524	143	3218	123	0	2	0
22036	1	191	4491	1575	144	3209	087	0	1	0
16017	1	186	4899	1549	147	3009	092	0	0	0
25029	1	186	5670	1664	149	2619	084	0	1	0
25019	1	190	5670	1664	149	2619	124	0	1	0
25049	1	188	4399	1727	149	3052	068	0	1	0

01008	1	186	4554	1626	151	3462	075	0	1	0
25028	1	183	4808	1626	139	3226	110	0	1	0
46003	1	209	7031	1664	173	3917	096	0	1	0
72002	1	203	5098	1651	173	3094	086	0	0	0
08010	1	203	4944	1549	178	3852	080	0	2	0
30037	1	209	4808	1613	197	3178	060	0	1	0
16029	1	213	6129	1676	199	4030	064	0	2	0
32013	1	179	5534	1637	145	2504	090	0	1	0
22019	1	179	4449	1549	151	3390	088	0	1	0
29028	1	243	6350	1689	231	3638	092	0	2	0
31017	1	254	4554	1562	167	3672	104	0	2	0
31024	1	192	4627	1626	124	2686	119	0	2	0
25031	1	202	5126	1651	128	2489	084	0	2	0
13006	1	198	4944	1676	131	2648	100	0		0
23044	1	201	4554	1575	131	2880	108	0	2	0
36013	1	196	5171	1676	130	2617	113	0	2	0
36014	1	196	6350	1600	142	2234	105	0	1	0
11008	1	198	4627	1586	142	3067	096	0	1	0
76003	1	192	5987	1689	144	2407	103	0	2	0
21028	1	198	4853	1586	149	3060	100	0	0	0
24036	1	192	5715	1689	156	2734	136	0	1	0
10019	1	198	6441	1626	158	2460	096	0	1	0
70004	1	197	5035	1549	158	3146	076	0	1	0
19020	1	202	5488	1676	161	2926	100	0	1	0
08009	1	203	4627	1562	161	3471	084	0	1	0
23027	1	202	4944	1486	165	3397	072	0	2	0
49003	1	197	5080	1613	169	3534	102	0	1	0
39008	1	200	6260	1676	171	2724	120	0	1	0
11006	1	193	4309	1524	173	4008	096	0	1	0
22033	1	201	6350	1715	174	2759	104	0	1	0
23041	1	197	6214	1727	176	2893	129	0	2	0
33027	1	192	6169	1715	176	2853	080	0	1	0
22035	1	197	5670	1575	179	3163	080	0	2	0
33022	1	201	4989	1676	179	3594	120	0	2	0
07026	1	200	4989	1562	184	3602	096	0	1	0
39010	1	195	5488	1549	185	3367	084	0	1	0
79002	1	196	5897	1588	187	3171	104	0	1	0
33025	1	193	5806	1689	187	3241	100	0	1	0
23043	1	203	5897	1676	188	3190	119	0	1	0
14020	1	203	5080	1600	188	3703	089	0	2	0
14019	1	196	4808	1651	186	3913	116	0	1	0
40003	1	197	5851	1702	189	3254	104	0	1	0
59002	1	202	5534	1664	189	3419	092	0	1	0
20030	1	194	5851	1651	191	3271	088	0	2	0
23040	1	197	5851	1702	191	3273	095	0	0	0
29032	1	196	5987	1638	193	3215	088	0	2	0
29027	1	197	5715	1575	193	3368	072	0	1	0
04005	1	192	5035	1499	193	3824	093	0	1	0
21023	1	207	4445	1651	205	4602	080	0	2	0
31030	1	209	5126	1651	206	4013	084	0	1	0
30034	1	204	4853	1651	210	4330	092	0	2	0
35036	1	210	5942	1727	211	3554	084	0	2	0
16025	1	210	6350	1626	212	3343	076	0	1	0
33020	1	211	5488	1626	217	3949	068	0	2	0
08011	1	209	4445	1410	218	4899	100	0	2	0
30035	1	209	5897	1651	219	3745	060	0	2	0
13007	1	206	5670	1676	224	3958	088	0	0	0
39009	1	206	4808	1549	227	4714	092	0	2	0
43009	1	209	6577	1651	228	3462	080	0	0	0
15012	1	206	4989	1524	228	4564	068	0	2	0

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24023	1	206	6485	1671	170	2748	092	0	1	1
30003	1	210	5761	1676	170	5112	092	0	1	1
14021	1	214	6214	1486	191	5080	086	0	1	1
46002	1	209	4765	1570	190	4006	116	0	1	1
42003	1	213	5171	1638	201	3893	090	0	0	1

FIELD EXPERIMENT Males n = 499

a	b	c	d	e	f	g	h	i	j	k
26015	0	215	5851	1676	205	3497	086	1	2	0
16007	0	205	6305	1803	216	3420	080	1	1	0
29017	0	207	6669	1689	218	3266	096	1	1	0
01006	0	211	5987	1842	220	3675	076	1	1	0
14008	0	206	4309	1600	221	5152	068	1	1	0
22005	0	208	5715	1702	222	3889	064	1	1	0
30019	0	208	5715	1778	229	4004	076	1	2	0
07007	0	207	6715	1854	232	3457	092	1	2	0
30006	0	202	7847	1803	341	4346	084	1	2	0
20002	0	200	7484	1727	347	4630	072	1	0	0
22014	0	192	6940	1727	350	3040	068	1	1	0
35005	0	203	6669	1765	352	3278	068	1	1	0
26013	0	196	5897	1702	360	6136	072	1	1	0
28005	0	196	5534	1676	363	6559	080	1	1	0
10002	0	194	6622	1829	369	3565	096	1	1	0
30011	0	202	6305	1778	371	3850	076	1	1	0
19006	0	203	7212	1778	394	3460	080	1	1	0
03002	0	194	6350	1765	402	6325	048	1	1	0
24003	0	202	7121	1715	442	6210	062	1	0	0
29012	0	246	5488	1676	337	6134	060	1	2	0
30012	0	246	7983	1892	328	4106	064	1	2	0
30010	0	259	7484	1880	319	4263	096	1	2	0
38002	0	218	6669	1676	295	4421	080	1	0	0
30008	0	217	6033	1727	296	4905	056	1	2	0
24007	0	217	7892	1778	297	3763	064	1	2	0
10012	0	221	6804	1803	306	4495	092	1	2	0
60003	0	219	8391	1755	315	3749	096	1	0	0
07015	0	220	5670	1765	325	5723	080	1	2	0
21005	0	224	6552	1842	326	5016	060	1	2	0
15002	0	217	8437	1727	341	4041	056	1	1	0
07016	0	220	6260	1753	347	5525	066	1	1	0
50001	0	193	4554	1524	229	5024	096	1	1	0
14007	0	203	7711	1880	234	5058	100	1	2	0
05003	0	203	7076	1715	237	5342	118	1	1	0
30021	0	203	7575	1778	243	5209	080	1	2	0
23013	0	198	6169	1791	244	5959	068	1	1	0
30004	0	201	5897	1702	244	4142	076	1	1	0
30005	0	202	5670	1753	244	4307	084	1	1	0
18003	0	197	6804	1676	252	5705	068	1	1	0
10003	0	196	5715	1755	252	4408	060	1	2	0
10004	0	202	6486	1755	253	5901	064	1	1	0
05001	0	198	5851	1765	253	4524	066	1	1	0
33005	0	196	8527	1755	255	2955	084	1	1	0
13002	0	194	8346	1651	255	5058	110	1	1	0
25017	0	202	6123	1740	260	4347	092	1	2	0
14004	0	196	5579	1676	268	4811	085	1	0	0
19003	0	194	6552	1880	275	4215	068	1	1	0
31006	0	202	6350	1791	286	4503	072	1	1	0
32007	0	200	6350	1715	290	4573	092	1	0	0
23004	0	203	7530	1778	292	5871	076	1	1	0
23011	0	193	6390	1727	292	4557	088	1	1	0

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1	1	0	1	1	1	1	1	1	1

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23024	0	200	6622	1803	227	3453	112	0	1	0
60001	0	197	5443	1651	227	4203	092	0	2	0
17001	0	194	7938	1829	230	2898	103	0	1	0
26007	0	193	7348	1727	230	3128	072	0	1	0
29018	0	195	7938	1651	232	2924	109	0	1	0
31008	0	198	6804	1867	235	3450	091	0	1	0
09001	0	202	5307	1803	237	4456	108	0	2	0
29010	0	193	5897	1702	239	4048	146	0	1	0
23002	0	202	7575	1803	241	3180	106	0	2	0
23012	0	201	6758	1778	244	3614	088	0	2	0
79001	0	197	5851	1676	244	4173	096	0	1	0
06001	0	201	6895	1778	248	3589	076	0	2	0
26017	0	201	5307	1600	248	4664	068	0	1	0
33006	0	197	6804	1778	252	3703	080	0	1	0
33012	0	203	5942	1727	253	4258	076	0	2	0
37005	0	203	7394	1778	255	3452	064	0	0	0
33004	0	201	6985	1753	256	3670	072	0	1	0
04001	0	201	6169	1791	259	4190	068	0	0	0
40002	0	197	5579	1727	259	4633	060	0	1	0
26016	0	198	5443	1626	259	4749	064	0	1	0
29011	0	200	5897	1727	264	4477	056	0	2	0
01003	0	200	6940	1753	268	3868	100	0	1	0
27004	0	196	4763	1613	272	5705	082	0	0	0
29005	0	202	5851	1702	276	4719	095	0	1	0
36003	0	193	5534	1740	276	4990	074	0	1	0
19002	0	193	7076	1854	278	3933	092	0	1	0
77001	0	198	5216	1651	278	5355	064	0	2	0
31013	0	193	5806	1740	280	4813	088	0	1	0
23010	0	192	6350	1715	281	4418	084	0	1	0
23016	0	194	6350	1829	281	4418	084	0	1	0
20013	0	199	6441	1829	285	4423	070	0	2	0
19005	0	197	5307	1626	287	5410	084	0	0	0
14002	0	192	8391	1816	288	3434	064	0	0	0
12002	0	202	6486	1600	288	4443	090	0	1	0
07002	0	192	6486	1791	290	4477	100	0	2	0
35022	0	202	6577	1727	294	4466	064	0	2	0
22013	0	195	5806	1676	295	5078	080	0	1	0
75002	0	199	6260	1702	296	4727	072	0	0	0
65001	0	202	6078	1803	297	4886	064	0	1	0
07004	0	201	5534	1727	297	5367	060	0	0	0
40003	0	196	6078	1651	304	4995	100	0	0	0
20014	0	195	6713	1676	305	4539	080	0	1	0
23024	0	192	6660	1727	306	4589	076	0	1	0
23026	0	203	7121	1803	307	4310	066	0	1	0
14003	0	195	6260	1753	308	4920	096	0	1	0
33016	0	196	6622	1676	312	4718	064	0	1	0
35018	0	198	6441	1753	312	4830	101	0	1	0
39002	0	200	6260	1778	321	5152	068	0	1	0
26021	0	203	5670	1791	323	5704	060	0	1	0
35023	0	196	5443	1651	323	5941	072	0	1	0
21001	0	197	8482	1854	328	3864	066	0	2	0
40001	0	198	5897	1727	328	5558	060	0	1	0
27005	0	201	6804	1803	334	4915	062	0	0	0
25007	0	222	5761	1778	268	4659	080	0	2	0
21008	0	184	6577	1727	372	5653	088	0	1	0
33008	0	205	5398	1702	240	4443	116	0	2	0
22015	0	211	5443	1715	241	4426	072	0	1	0
43002	0	209	7348	1727	243	3309	068	0	2	0
20001	0	211	7121	1816	250	3507	090	0	1	0
60002	0	206	7031	1753	250	3552	072	0	0	0

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32003	0	210	7711	1791	272	3523	060	0	2	0
35003	0	206	6214	1745	276	4443	092	0	1	0
72001	0	214	4554	1626	276	6063	068	0	1	0
35008	0	214	6441	1740	283	4389	068	0	2	0
47001	0	209	5443	1753	283	5194	072	0	1	0
32008	0	213	6123	1689	286	4671	058	0	1	0
24011	0	209	6078	1854	287	4723	080	0	2	0
51002	0	207	6486	1791	288	4443	080	0	0	0
21009	0	210	6441	1740	288	4475	072	0	1	0
26002	0	205	6260	1816	290	4659	072	0	2	0
70001	0	205	5488	1676	292	5512	056	0	0	0
33011	0	205	7756	1778	294	3756	068	0	0	0
22009	0	204	6305	1676	294	4659	080	0	2	0
07009	0	212	5942	1715	294	4942	072	0	0	0
07011	0	212	7620	1829	295	3869	088	0	0	0
63001	0	208	7167	1778	295	4113	064	0	0	0
22001	0	213	6577	1715	295	4483	088	0	1	0
73002	0	204	6214	1740	295	4744	064	0	1	0
29002	0	206	8165	1753	299	3664	098	0	1	0
23020	0	207	7257	1753	303	4169	093	0	1	0
25015	0	212	8119	1740	304	3739	084	0	1	0
10009	0	213	7484	1778	304	4057	080	0	0	0
20012	0	206	7348	1664	305	4147	076	0	2	0
64002	0	210	6350	1753	307	4833	060	0	1	0
30016	0	206	7212	1689	308	4270	088	0	0	0
21015	0	208	6985	1842	309	4425	084	0	2	0
20005	0	208	9253	1791	310	3353	080	0	2	0
24017	0	214	7076	1803	312	4415	080	0	1	0
33007	0	213	6305	1715	312	4954	084	0	0	0
26009	0	212	6532	1727	317	4850	064	0	1	0
22002	0	205	5761	1689	317	5499	068	0	1	0
21006	0	213	7575	1803	323	4269	088	0	0	0
07008	0	211	6669	1854	330	4948	056	0	2	0
24003	0	207	7575	1753	334	4414	068	0	0	0
21010	0	213	6260	1676	343	5516	076	0	1	0
26005	0	206	6713	1791	350	5211	064	0	2	0
33010	0	205	5443	1689	350	6426	056	0	0	0
21003	0	208	6895	1753	354	5157	088	0	0	0
24019	0	214	8255	1803	356	4318	092	0	0	0
15006	0	209	9072	1854	361	5978	080	0	0	0
23017	0	208	7484	1905	363	4850	092	0	1	0
29021	0	207	6713	1842	363	5408	060	0	2	0
75003	0	209	7076	1778	369	5207	064	0	0	0
15004	0	207	5534	1676	369	6658	076	0	0	0
26003	0	212	7439	1778	371	4983	080	0	0	0
78001	0	205	6895	1778	376	5456	064	0	0	0
51003	0	208	6758	1829	380	5616	056	0	0	0
24016	0	209	6396	1702	394	6157	056	0	1	0
17003	0	206	6758	1803	399	5903	100	0	0	0
48001	0	207	6985	1753	405	5795	064	0	1	0
05005	0	214	8119	1715	407	5013	076	0	0	0
07006	0	205	7031	1727	419	5961	072	0	1	0
44001	0	207	7212	1854	422	5856	100	0	2	0
01004	0	205	5761	1727	426	7390	064	0	0	0
15001	0	213	6940	1791	427	6150	074	0	0	0
08004	0	205	6622	1803	437	6595	072	0	0	0
51001	0	213	8255	1816	448	5423	076	0	0	0
27001	0	210	8573	1930	468	5453	070	0	1	0
02003	0	209	7305	1816	506	6929	066	0	0	0
16001	0	188	5670	1524	163	2911	104	0	1	0

35001	0	190	4944	1753	186	6760	108	0	1	0
20011	0	189	6078	1776	211	6475	124	0	0	0
23009	0	184	5761	1778	230	5991	062	0	1	0
26014	0	184	5851	1778	232	5967	072	0	1	0
31009	0	188	4989	1638	234	4696	107	0	1	0
36009	0	188	4853	1689	237	4873	084	0	1	0
30003	0	189	5851	1753	241	4117	080	0	0	0
01001	0	187	5216	1664	246	4723	083	0	1	0
13001	0	189	5216	1626	246	4723	076	0	1	0
23019	0	189	4082	1575	248	6063	084	0	1	0
25005	0	191	6350	1753	255	4019	096	0	1	0
23008	0	190	6033	1776	256	4248	064	0	1	0
24009	0	181	6169	1791	281	4657	092	0	1	0
23006	0	191	7303	1791	283	3871	088	0	1	0
24013	0	186	6123	1715	288	4707	080	0	1	0
33014	0	186	4899	1664	288	5883	084	0	2	0
07001	0	185	5987	1549	294	4906	080	0	0	0
11001	0	189	5942	1753	295	4961	096	0	1	0
20008	0	188	5670	1727	295	5200	088	0	0	0
31010	0	188	7303	1791	303	4143	064	0	0	0
26019	0	188	6622	1803	303	4568	072	0	1	0
15005	0	184	6350	1715	312	4919	088	0	0	0
29015	0	186	7167	1702	321	4481	084	0	1	0
29019	0	189	4944	1753	321	6497	080	0	1	0
28002	0	190	5534	1703	326	5884	068	0	1	0
10001	0	189	6078	1727	327	5375	080	0	0	0
36007	0	190	6078	1638	327	5375	080	0	1	0
24001	0	184	6441	1727	328	5090	066	0	0	0
36008	0	186	5352	1727	338	6310	080	0	1	0
26020	0	189	4808	1676	339	7047	072	0	1	0
26010	0	181	7847	1778	350	4458	068	0	1	0
68002	0	227	6662	1715	275	4128	092	0	1	0
16009	0	211	6123	1740	264	4312	092	0	2	0
16009	0	211	6123	1740	264	4312	092	0	2	0
24004	0	214	5171	1676	141	2723	120	0	2	1
29006	0	207	5443	1689	220	4041	100	0	2	1
03001	0	211	6260	1727	229	3655	092	0	0	1
26018	0	198	8936	1676	337	3766	088	0	1	1
29001	0	198	6895	1740	394	5711	064	0	0	1
39003	0	192	7938	1816	399	5030	066	0	1	1
25002	0	175	5352	1727	216	4028	107	0	1	1
14001	0	178	6577	1829	319	4850	085	0	1	1
33015	0	179	6713	1664	232	3457	080	0	1	1
20003	0	199	5352	1613	207	3864	078	0	2	1
12001	0	195	5761	1854	230	3991	100	0	1	1
19004	0	194	6350	1753	234	3689	107	0	1	1
36006	0	195	4672	1638	263	3628	084	0	1	1
24012	0	194	6940	1842	266	3836	076	0	2	1
29003	0	197	6577	1803	272	4152	106	0	2	1
57002	0	195	5761	1702	272	4716	076	0	1	1
25003	0	195	5262	1676	275	5246	076	0	1	1
42001	0	202	5897	1778	276	4682	078	0	0	1
33017	0	192	5625	1765	278	4948	090	0	1	1
08002	0	195	5443	1740	287	5275	096	0	0	1
02001	0	199	5806	1702	297	5115	070	0	0	1
33009	0	198	7620	1854	303	3970	080	0	1	1
39004	0	192	5443	1740	306	5618	076	0	0	1
17002	0	199	5307	1664	307	5763	076	0	2	1
24014	0	195	5715	1664	320	5735	064	0	1	1
21019	0	192	6350	1753	329	5180	070	0	1	1

34006	0	207	4082	1719	24	5075	060	0	1	1
35006	0	206	5806	1689	255	4396	064	0	1	1
24015	0	229	7306	1765	300	4112	084	0	2	1
25012	0	216	7394	1829	255	5452	068	0	2	1
51004	0	216	5987	1664	261	6027	048	0	0	1
32002	0	217	7620	1803	433	5688	060	0	1	1
16012	0	216	5488	1651	275	5011	060	0	1	1
16013	0	217	7257	1753	283	3895	082	0	1	1
31002	0	211	5262	1664	266	4949	062	0	2	1
22004	0	206	8165	1803	281	3455	060	0	2	1
19008	0	212	7257	1727	287	3957	084	0	1	1
17004	0	208	5488	1638	301	5492	084	0	1	1
31007	0	205	7847	1740	321	4093	068	0	2	1
35010	0	204	6985	1765	376	5386	060	0	0	1
23014	0	185	4899	1676	141	2874	100	0	1	1
75001	0	186	4309	1613	187	4340	095	0	0	1
30001	0	191	4627	1613	196	4232	092	0	0	1
31004	0	186	6396	1727	219	3422	076	0	0	1
30022	0	191	6486	1842	223	3443	080	0	2	1
32011	0	187	5171	1613	240	4638	052	0	1	1
30002	0	182	5443	1689	244	4487	096	0	0	1
18002	0	190	5352	1702	253	4727	080	0	1	1
35007	0	186	6260	1715	268	4288	092	0	1	1
18001	0	191	6577	1778	272	4132	122	0	1	1
28003	0	189	6804	1829	292	4285	064	0	1	1
08001	0	186	5534	1702	295	5327	092	0	0	1
04002	0	188	5670	1778	318	5607	068	0	0	1
25006	0	180	6849	1829	350	5107	100	0	1	1

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